



Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry of Transport
and Digital Infrastructure

Investigation Report 470/15

Less Serious Marine Casualty

**Collision between the EMSMOON
and Friesenbrücke
railway bridge
at Weener, Ems,
on 3 December 2015**

23 February 2017

The investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG) of 16 June 2002, amended most recently by Article 1 of 22 November 2011, BGBl. (Federal Law Gazette) I p. 2279.

According to said Law, the sole objective of this investigation is to prevent future accidents and malfunctions. This investigation does not serve to ascertain fault, liability or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this investigation report.

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1 Summary

At 1823¹ on 3 December 2015, the Antigua & Barbuda-flagged general cargo ship EMSMOON, which was sailing in ballast with the outgoing tide, collided with the Friesenbrücke railway bridge at Weener, Ems, in good visibility and southerly winds of 3-4 Bft. The bascule bridge was completely destroyed in the process. The ship sustained only minor damage in the bow section. The train between Weener and Leer was stopped in good time three minutes before the collision at the distance signal 700 m away. There were no injuries and no pollutants escaped.

¹ Unless stated otherwise, all times shown in this report are local = UTC + 1.

2 FACTUAL INFORMATION

2.1 Photo



Figure 1: Photo of ship

2.2 Ship particulars

Name of ship:	EMSMOON
Type of ship:	General cargo vessel
Nationality/Flag:	Antigua & Barbuda
Port of registry:	Saint John's
IMO number:	9213894
Call sign:	V2BN3
Owner:	Grona Shipping GmbH & Co. KG
Year built:	2000
Shipyard/Yard number:	Scheepswerf Ferus Smit B.V./326
Classification society:	DNV GL
Length overall:	111.75 m
Breadth overall:	14.95 m
Gross tonnage:	4,563
Deadweight:	6,334.8 t
Draught (max.):	6.37 m
Engine rating:	3,280 kW
Main engine:	Wärtsilä 8 R 32 LNE
(Service) Speed:	12 kts

Hull material:	Steel
Hull design:	Double bottom
Minimum safe manning:	9

2.3 Voyage particulars

Port of departure:	Papenburg
Port of call:	Sodertalje, Sweden
Type of voyage:	Merchant shipping, international
Cargo information:	Unladen vessel
Manning:	10
Draught at time of accident:	4.20 m
Pilot on board:	Yes
Number of passengers:	None

2.4 Marine casualty or incident information

Type of marine casualty:	Less serious marine casualty, collision
Date, time:	03/12/2015, 1823
Location:	Weener, Ems
Latitude/Longitude:	φ 53°09.7'N λ 007°22.3'E
Ship operation and voyage segment:	Harbour mode Passing a bridge
Place on board:	Fore section
Human factors:	Yes, human error Yes, violation
Consequences (for people, ship, cargo, environment, other):	Minor damage to ship, bascule bridge destroyed, no injuries or environmental damage

2.5 Shore authority involvement and emergency response

Agencies involved:	Vessel Traffic Service (VTS) Emden
Resources used:	Tug GERT BLIEDE
Actions taken:	Section closed
Results achieved:	Sailed back to Papenburg

Extract from Nautical Chart 92,
 Federal Maritime and Hydrographic Agency (BSH)

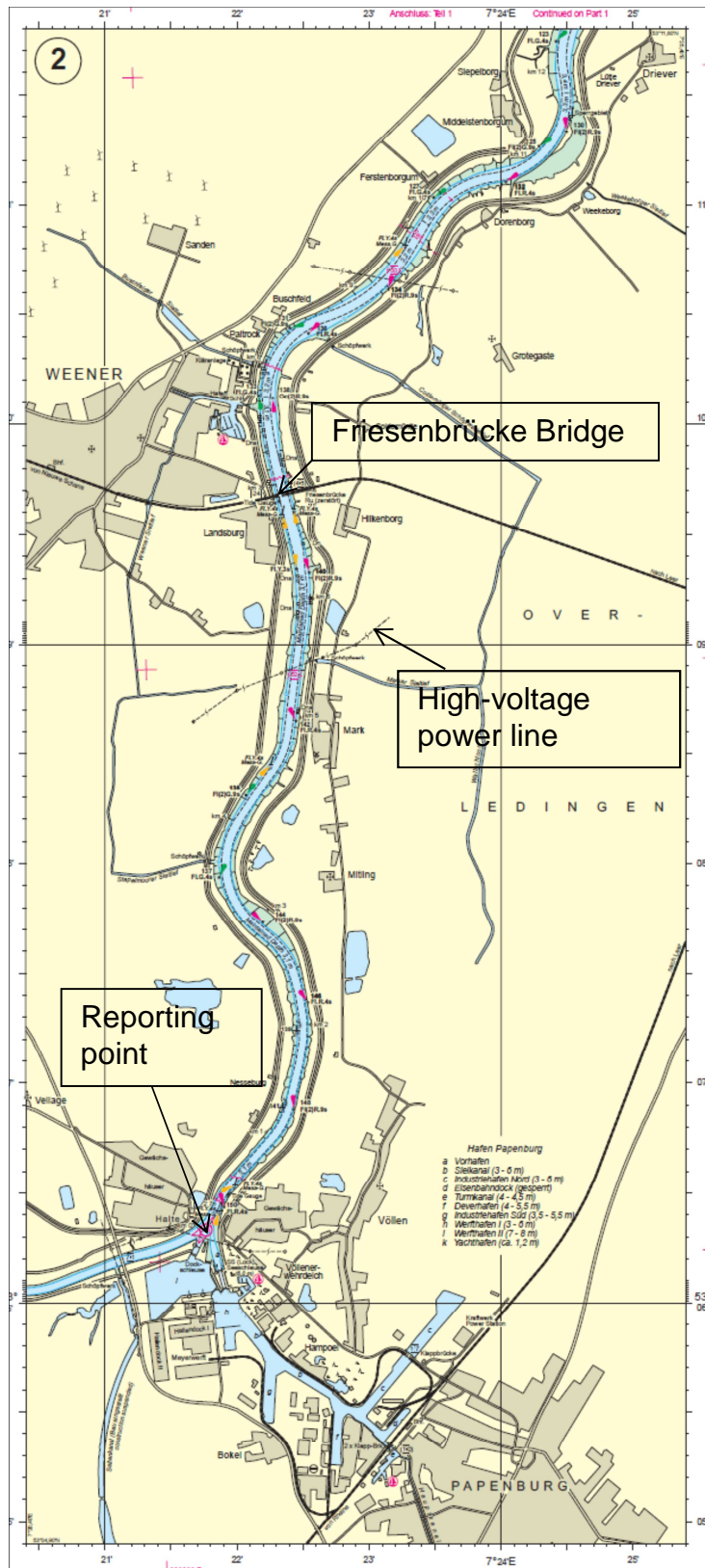


Figure 2: Nautical chart

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident according to the pilot of the EMSMOON's testimony and audio recordings

The pilot boarded the EMSMOON in Papenburg at 1600 on 3 December 2015. The ship was unladen and her draught aft was 4.20 m. She was made fast with her starboard side in the Sielkanal. The master and a watchkeeping officer were on the bridge, as was an engineer at times. The EMSMOON calls at Papenburg quite often, meaning the crew is familiar with the area. The rudder and controls were explained to the pilot and the master was informed about the area. The bow thruster adjustments on the starboard wing conning position were out of position and about 30% off-centre. Apart from that, the navigational equipment was reportedly in proper working order. As on previous voyages, the pilot was to take charge of manoeuvring at locks and bridges. Trains were expected to cross Friesenbrücke Bridge at Weener at 1823 and 1838.

The EMSMOON casted off at 1620 and turned in the Industriehafen Süd industrial port. The lock was still occupied by the outbound GERDA. At about 1650, the EMSMOON's starboard side was made fast in the lock, where fresh water was taken on board and waste disposed of. At 1745, the EMSMOON sailed out of the lock and a report was made to VTS Emden and the Friesenbrücke Bridge (Weener Bridge) on VHF channel 15 for the first time at the reporting point plotted on the navigational chart. An ebb tide prevailed and there were southerly winds of 3-4 Bft with gusts of up to 6 Bft from aft at the scene of the accident. At half ahead, she made good a speed over ground (SOG) of 8 kts. This corresponded to a speed through water (STW) of about 5-6 kts. The swell on the sides was reportedly barely noticeable. The officer on watch directed the wing searchlights about 1-1.5 ship lengths ahead at the piles.

At 1807, the inland waterway tanker STORM reports on the local radio channel that she is behind the EMSMOON and asked by Weener Bridge when she intends to pass through. "Well, the train comes at 23. If it passes through then – by half." The time of 1823 is confirmed by the STORM, referring to the EMSMOON that they do not know how fast she is. WEENER BRIDGE then basically asks the STORM to increase her speed.

At 1814, the unladen inland waterway vessel CYBERNETICA reports in to Ems Traffic for a voyage from Herbrum to Delfzijl. Herbrum is located south of Papenburg. The Ems is a navigable inland waterway there. The navigable maritime waterway starts downstream at Papenburg.

At 1815, the EMSMOON sent her second message to Weener Bridge (keeper of Friesenbrücke Bridge) on VHF channel 15 about 3 cbl south of the high-voltage power line at beacon 142. It was reportedly 1808 according to the pilot's watch. After the bridge keeper once again confirmed his understanding of the train crossing times,

he reportedly replied that he wanted to continue quickly. He then reportedly calculated that they would arrive at the bridge at about 1818.

About two minutes later, beneath the high-voltage power line, the pilot recalls that he reportedly sent a third message to Weener Bridge, asking about the situation. Weener Bridge reportedly replied: "The train is delayed. It will come at 26. You can pass." The pilot reportedly then replied: "Super, I will continue as before then." Based on this communication, the pilot assumed the bascule bridge would be open. Consequently, he allowed the EMSMOON to continue with no reduction in speed.

At 1818, the inland waterway tanker STORM, which was following the EMSMOON, reported in to Weener Bridge with the request that she was 500 metres behind the EMSMOON and would also like to pass through the bascule bridge. Weener Bridge reportedly replied let us see how you get on, the EMSMOON should be here in five minutes, I am letting her through right away. This again led the pilot to reportedly conclude that the bridge is open, as the STORM has reportedly closed in even further.

The sky was overcast and the night very dark. About 6 cbl (1.1 km) south of the Friesenbrücke Bridge, they started to reduce in small steps and the pitch of the controllable pitch propeller was set to 20% (dead slow ahead). Upon reaching light-post 140 (about km 6), the ability to steer had reportedly dropped significantly. Therefore, the pitch was increased back to 30-35% (slow ahead). After passing light-post 140, the EMSMOON was on a straight section before the bridge. It was only possible to make out the bright floodlights, however. The bascule bridge was not visible in the dark. It was reportedly not possible to make out the bridge signals due to the floodlit foundations of the passage and bright lights of the factory situated in the background. In addition, the HEGEMANN dredger was behind the bridge at the trestle with fully set navigation lights and bright deck spotlights.

At 1820, just north of light-post 140, the EMSMOON reported in to the Jann-Berghaus Bridge (Leer Bridge) on VHF channel 15, stating that she would be at Weener Bridge directly and at km 13 in about half an hour, probably slightly more. The bridge is located at km 15.

At 1822, the Weener Bridge made contact with the surprising news for the pilot that the EMSMOON must stop and the bridge is closed. At this point, the EMSMOON was still some 1.5 ship lengths away from the passage. The pitch was immediately put to full astern. This manoeuvre failed to reduce the speed significantly, however. The collision with the closed bascule bridge occurred at 1823.

After the collision, the engine was stopped and VTS Emden informed about the accident and the damage. At 1829, VTS Emden ordered the closure of the section between Leer and Papenburg and the tug GERT BLIEDE was requested from Papenburg at 1834. The tug made fast on the EMSMOON at 1946. The EMSMOON was to be gently pulled clear with tug assistance, so as to limit the damage.

A bridle was attached to the EMSMOON's stern, which ran from the port and starboard fairleads on the transom stern to the towline. It was then possible for the tug to pull the EMSMOON clear with the assistance of the ship's rudder and engine at about 2000. At 2030, the folding part of the bridge fell into the water. The ship sustained only minor indentations on the bow section. No pollutants escaped. The EMSMOON then sailed astern with tug assistance back to Papenburg, where after passing through the lock at 2300 she made fast in the Industriehafen Süd industrial port on her starboard side.

3.2 Investigation

In addition to the testimony of the EMSMOON's pilot, the BSU received testimony from various vessels sailing toward Emden (the ATLANTIC, GERDA and STORM), as well as from shore-based sources about the situation at the Friesenbrücke Bridge's signal box. This testimony concerning the radio communications on the Papenburg/Emden section is indicative of the traffic and navigation practices. The GERDA left the lock in Papenburg about one hour before the EMSMOON. The inland waterway tanker STORM, assuming she could pass the bascule bridge in a convoy, was about 500 metres behind the EMSMOON immediately before the collision with the Friesenbrücke Bridge. Furthermore, the BSU conducted two inspections and two surveys of the scene of the accident and visited both the VTS and the pilot station in Emden.

3.2.1 Testimony of the master concerning the passage of the ATLANTIC

The ATLANTIC left the lock in Papenburg for Emden in the dark at 0645 on the morning of 3 December 2015 in good visibility under pilotage. A passage signal was not visible before the Friesenbrücke Bridge. The pilot was informed of this and then asked the bridge keeper specifically. Manoeuvring speed was reduced to the minimum. Radiotelephony was used to announce in German that the bridge is reportedly open and safe passage possible. There was also reportedly communication between the VTS and Weener Bridge in the background. The searchlight was then directed at the bascule bridge, making it possible to see the open bascule clearly. The Jann-Berghaus Bridge was passed at 0735 and Emden then reached following a calm voyage. The waterway police (WSP) boarded and checked the ship's papers while she was laid up in Emden. The accident at the Friesenbrücke Bridge was also discussed. The police was informed that no bridge signals were seen.

3.2.2 Testimony of the GERDA's pilot, who was monitoring the local radio channel

The GERDA sailed out before the EMSMOON and passed the Friesenbrücke Bridge at 1700. She left the lock in Papenburg at 1625. She monitored VHF channel 15 continuously while en route to Emden and it was possible to follow the radio communications on this channel during the period in question. The EMSMOON reported in to Weener Bridge for the first time in the lock at Papenburg and stated she would arrive in 40-45 minutes. A second radio contact reportedly took place, in which the train crossing times were confirmed as 1823 and 1838. A third call was made at the informal reporting point beneath the high-voltage power line south of Friesenbrücke Bridge. At this point, preparations are normally made to open the bridge or the ship is advised that the bridge cannot be opened. When Weener Bridge was asked if EMSMOON could continue slowly or thus, it was reportedly said that the train was delayed three minutes and the EMSMOON could pass through. This was received positively on the EMSMOON, as she could continue thus and assume that the passage would be at 1820. Moreover, the inland waterway tanker STORM apparently wanted to use the same opening slot. Weener Bridge reportedly said that the seagoing ship would come first and then they will see. A fourth radio call was made immediately before the collision with the bridge. Weener Bridge called the EMSMOON, reportedly stating she must stop immediately because the bridge was not open. The EMSMOON was already directly in front of the bridge at this point. The collision was displayed at 1823 on the GERDA's portable pilot unit (PPU). The GERDA understood that the EMSMOON and STORM were supposed to pass before the delayed train.

3.2.3 Testimony of the master and the pilot of the following STORM

The Dutch skipper and a Dutch pilot were on the bridge of the inland waterway tanker STORM at 1822. The STORM's draught was 2.4 m and she was en route to Amsterdam laden with reformat. Visibility was good and no particular measures were taken due to the weather. The Dutch so-called 'auxiliary skipper' (pilot for inland waterway vessels) was at the helm. The STORM was 400-500 metres behind the EMSMOON. The EMSMOON's echo was clearly visible on the radar screen. Three VHF radiotelephones were on the bridge. The pilot operated one of those on channels 10 and 15. He also took charge of the radio communications in the area and – similar to the EMSMOON – reported in to the VTS and Friesenbrücke Bridge. The skipper listened in on the radio communications. The reception was reportedly loud and clear. An arrangement had been made with the EMSMOON to pass the Friesenbrücke Bridge together. This was reportedly confirmed several times by radiotelephone. The STORM was supposed to follow just behind the EMSMOON, as she believed that together they only had seven minutes to pass the bridge. That would be enough for both ships if they proceeded in close formation. A loud obscenity was suddenly heard on the EMSMOON. Only a continuous line could be seen on the radar screen and it was not clear whether the EMSMOON had rammed the bridge.

It was not possible to see whether the bascule was open or closed. The bridge signals could not be made out, either. After all, the STORM was directly behind the EMSMOON with her bright superstructure and forward visibility was restricted. It was pitch-black and no other lights were visible. The EMSMOON's searchlights were directed forward and the STORM could not understand why the bascule was not detected. Using the bow thruster, it was then possible to stop the STORM on the dolphins in time before the EMSMOON.

3.2.4 Testimony of the bridge keeper at the signal box in Weener (Friesenbrücke Bridge)

The EMSMOON reported in to Weener Bridge on VHF channel 15 at 1745 from the reporting point in Papenburg and requested that the bridge be opened in about 35 minutes. Owing to rail traffic from Groningen to Leer, an opening would not have been possible until between 1823 and 1830 on the train's outward run and not until 1838 on its return run. The train's departure times are provided by the traffic controller in Ihrhove. The clock in the signal box has reportedly never deviated from the departure times in 15 years. The bascule bridge takes about five minutes to open, meaning early opening would not have been possible when the time of arrival announced was 1820. Early bridge openings generally depend on the timetable of the trains and take place only on request if trains are cancelled or delayed by at least 20 minutes.

The EMSMOON reported in again at the high-voltage power line and wanted to take the first opening slot. The bridge was still closed due to the two to three minute train delay. Accordingly, the monitoring system displays the switch position 'Bridge closed' and the signals for shipping display two adjacent red lights with a white light above on both sides of the bridge. When the EMSMOON failed to stop and collided with the bascule bridge despite the bridge keeper's warning, the bridge keeper immediately stopped the train approaching from Groningen by setting the distance signal, which was 700 metres away, to 'Halt' from the signal box and notified the traffic controller in Ihrhove. The pedestrians were then warned verbally and the barriers closed. It is not possible to determine the ship's positions on the Ems from the signal box. The bridge keeper is equipped with neither radar nor AIS.

3.2.5 Visit to the scene of the accident by the BSU

The BSU visited the scene of the accident on 8 December 2015 to inspect the damage and recovery of the bascule. The bascule was completely destroyed and could only be lifted out by means of a floating crane. This made it possible to clear the passage for use by larger ships again.



Figure 3: Recovery of the bascule

The BSU recorded the new situation at the Friesenbrücke Bridge at Weener on 18 March 2016. In the meantime, the middle section of the bridge had been lifted out and a new lighting system installed. Seen from the southern side, the left-hand pier of the small passage (24 m) is now painted white and floodlit by the existing light. The large passage (46.6 m) is equipped with a new table sign, a new radar reflector, new floodlighting, and a new Blz. 4s warning beacon on both sides. The signal board belonging to the rail operator is removed (or out of operation on the northern side). The middle section and signal board are at the grounds of the Meyer Werft shipyard.



Figure 4: Bridge passage



Figure 5: High-voltage power line

3.2.6 BSU survey on the EMSMOON

The BSU met at the owner with representatives of the flag State of Antigua & Barbuda (MARCARE) on 18 March 2016 for the Papenburg to Emden survey on the EMSMOON, which took place in the evening. The course of the accident and next steps were discussed. The survey was merely for the purpose of detailed observation, without disrupting ship operations. In particular, the functioning of the ship's command with the pilot, the lighting conditions in the area, and the navigation equipment were to be documented in the process. The owner's executive director and fleet manager with lawyer, the new master, the new chief officer, two watchkeepers, a pilot, an alderman from the Emden Pilots' Association, two authorised representatives of the flag State of Antigua & Barbuda, and two BSU investigators were on the bridge during the survey.

3.2.6.1 EMSMOON's navigation equipment

The EMSMOON's navigation equipment included an Observator Pilot MK III magnetic compass, an Anschütz Standard 20 gyro compass, a Pilotstar D autopilot (track control system), Navigator MK10 GPS and Navigator MK10 DGPS Professional GPS receivers, two Furuno FR-2115 X-band (9 GHz) radar systems with bow antenna and Sperry Marine VisionMaster FT (where the latter was used for voyage data recorder (VDR) recordings), a Furuno Universal AIS FA-100 AIS, a Netwave NW-4010 simplified voyage data recorder (S-VDR), a Furuno Doppler DS-70 speed log, Furuno FE-700 echo-sounding equipment, and a CSI Watch Clock 596 BNWAS.

The navigation equipment is installed in a continuous row in the bridge console. The following radar images were made by the Sperry port radar system, which was also recorded on the VDR on the day of the accident. There was no speed information or variable range marker available, however. The Doppler log display was separate.

3.2.6.2 Master/pilot exchange, controls and bridge poster

Before the survey, the pilot gave the master detailed information on the route and in turn the pilot was informed about the EMSMOON's manoeuvring characteristics, i.e. a left-hand controllable pitch propeller, bow thruster, in ballast a turning circle diameter of 152 m, an advance distance of 750 m (stopping test in 312 s) or 300 m (crash stop in 81 s) at half ahead (9 kts) with the pitch at 50%. At dead slow on the minimum pitch, 3 kts is the lowest speed. The manoeuvring characteristics are summarised on the wheelhouse poster and displayed.

In reality, the pilot had command of the controls while casting off, moving astern and passing a ship moored behind the EMSMOON, sailing into and out of the lock at Papenburg, as well as during the remainder of the voyage up to Emden. The master operated the helm and controls. The chief officer kept the bell book and the two watchkeepers illuminated the piles on the port and starboard sides, which were equipped with reflectors. The Friesenbrücke Bridge was approached at 8 kts. Stopping in an aft current is reportedly extremely difficult. It is necessary to steer astern and use the bow thruster.

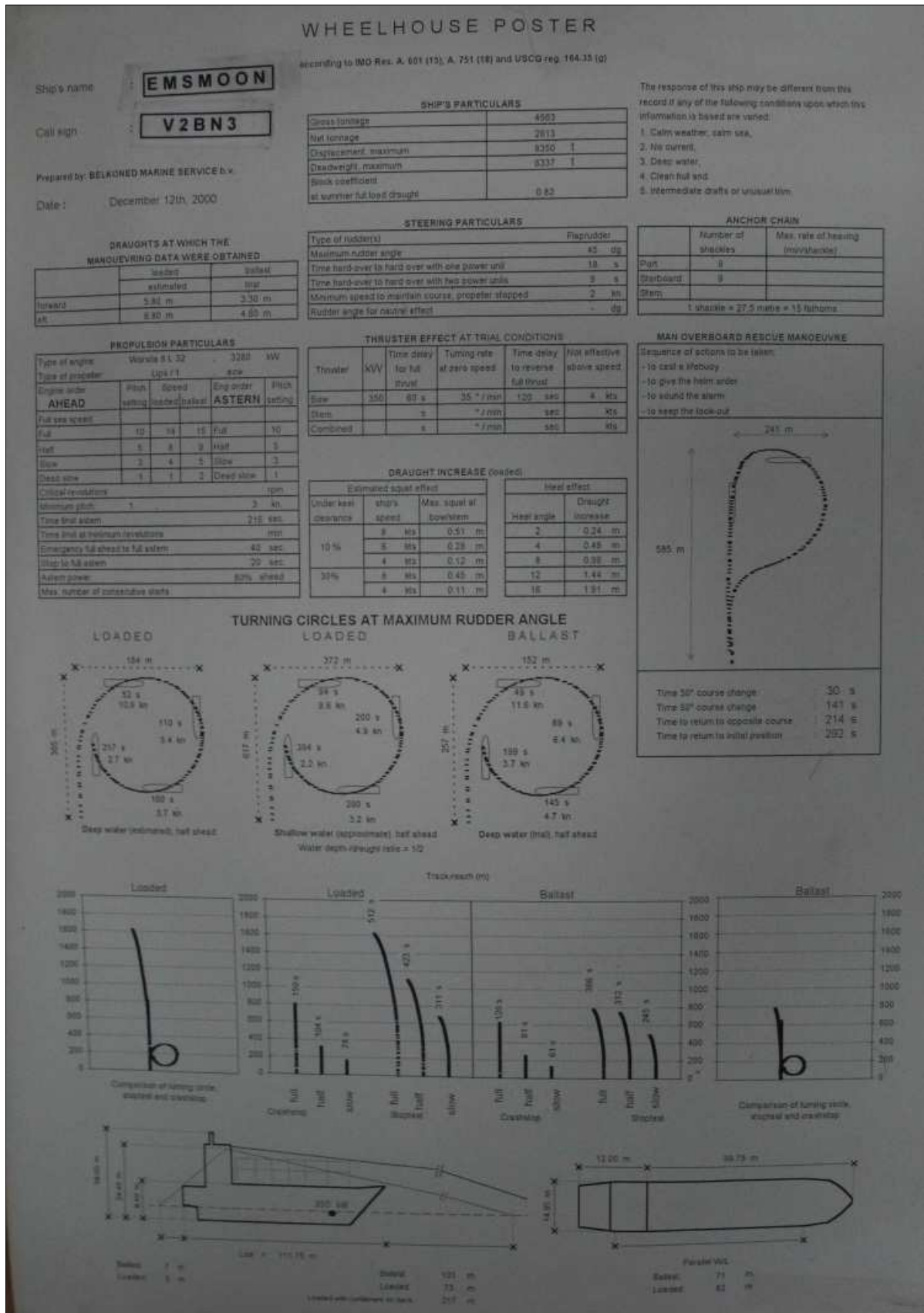


Figure 6: Wheelhouse poster, measured values in deep water

The EMSMOON does not have a separate steering position. The follow-up and non-follow-up steering² are integrated amidships in the bridge console, which is where the helmsman is also positioned. The radar screens are positioned to the left and right of the controls. Due to the darkness in the area and the unilluminated fairway marking piles, it is common practice to illuminate the sides with searchlights from the bridge wings. This is the only way to see the sea marks in time from the bridge. It shallows immediately behind them, posing a risk of grounding.



Figure 7: Follow-up and non-follow-up steering with tiller



Figure 8: Spotlight in the wing

The two radar images below show the curvature at the high-voltage power line at radar ranges of 0.5 and 0.75 nm. The high-voltage power line was an informal reporting point used by pilots for the bridge keeper when the bridge was still intact. The lighting system has now been changed and the bridge signals are extinguished. The middle section of the Friesenbrücke Bridge has also been lifted out in the meantime. Therefore, the wider middle passage was taken in the interest of safety.

The radar image showed an opening that was not central shortly before the bend in the river. All in all, the two passages became visible relatively late from a distance of about 0.25-0.3 nm.

² In follow-up steering mode, the required rudder angle is selected using the rudder position indicator. The servo mechanism of the steering gear is operated by an amplifier until the actual rudder angle coincides with the required rudder angle. The actual rudder position is transmitted to the rudder position indicator by the feedback unit.

In the case of non-follow-up steering, the steering gear is activated directly through contact connection at the non-follow-up tiller. The rudder position depends on the duration of the contact connection at the tiller. The tracking of the actual rudder position at the rudder position indicator must be monitored during the steering process.

Hand-wheels and mini-hand-wheels are generally designed for follow-up steering, while tillers and buttons are designed for non-follow-up steering. When electrical steering gear systems are used, two independent systems must always be available. Separate cables and lines must be provided for these steering gear systems.



Figure 9: Range of 0.75 nm at the high-voltage power line



Figure 10: Range of 0.5 nm at the high-voltage power line

The new lighting system came into view behind the high-voltage power line, which is some 8 cbl before the bridge. The lights of a factory were visible on the port side behind it. The bridge was not visible.

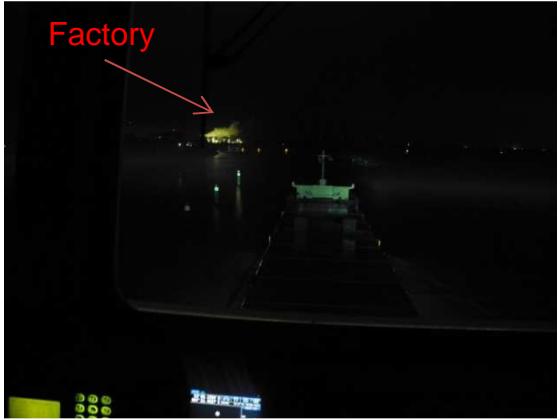


Figure 11: Factory with row of dolphins



Figure 12: Approach to the passage

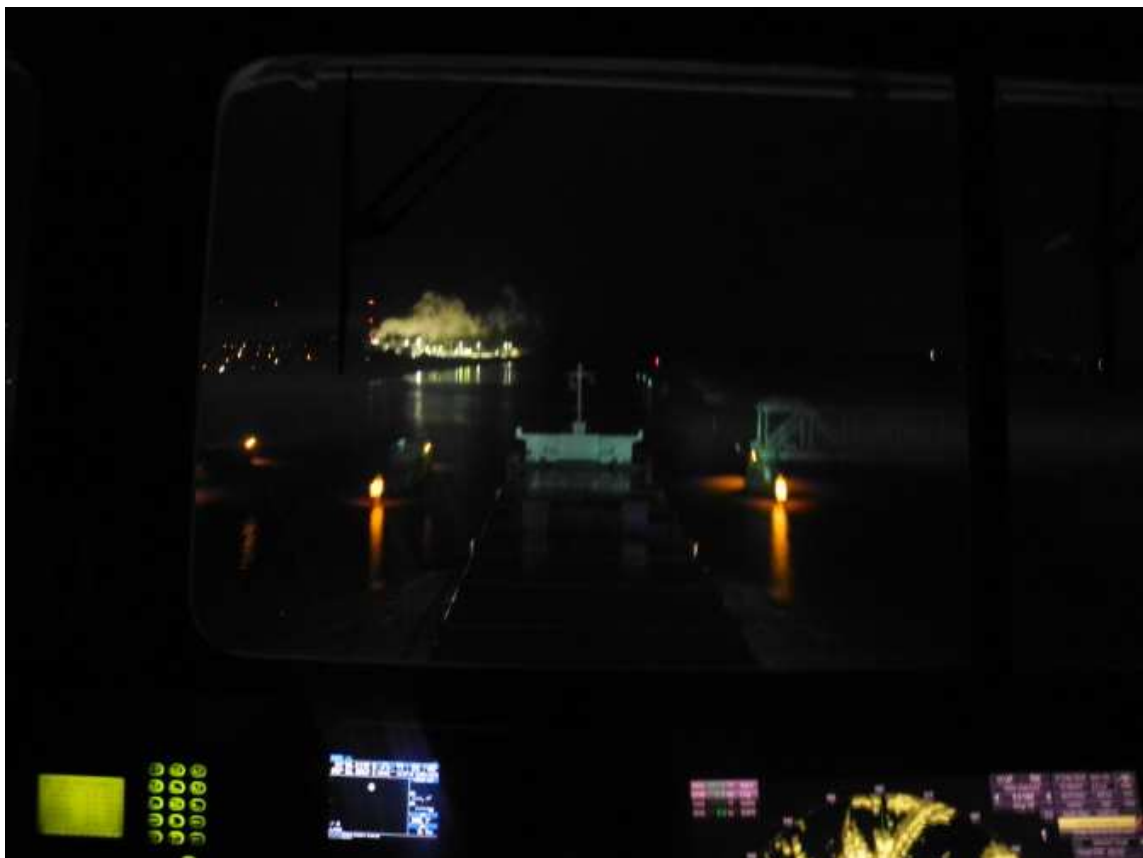


Figure 13: New middle passage

The Jann-Berghaus Bridge in Leer came into view about half an hour later. The signal lighting there was visible off Leda. They were still red during the approach. The bascules were not visible. The bridge was open according to the port radar and passed at 8 kts.

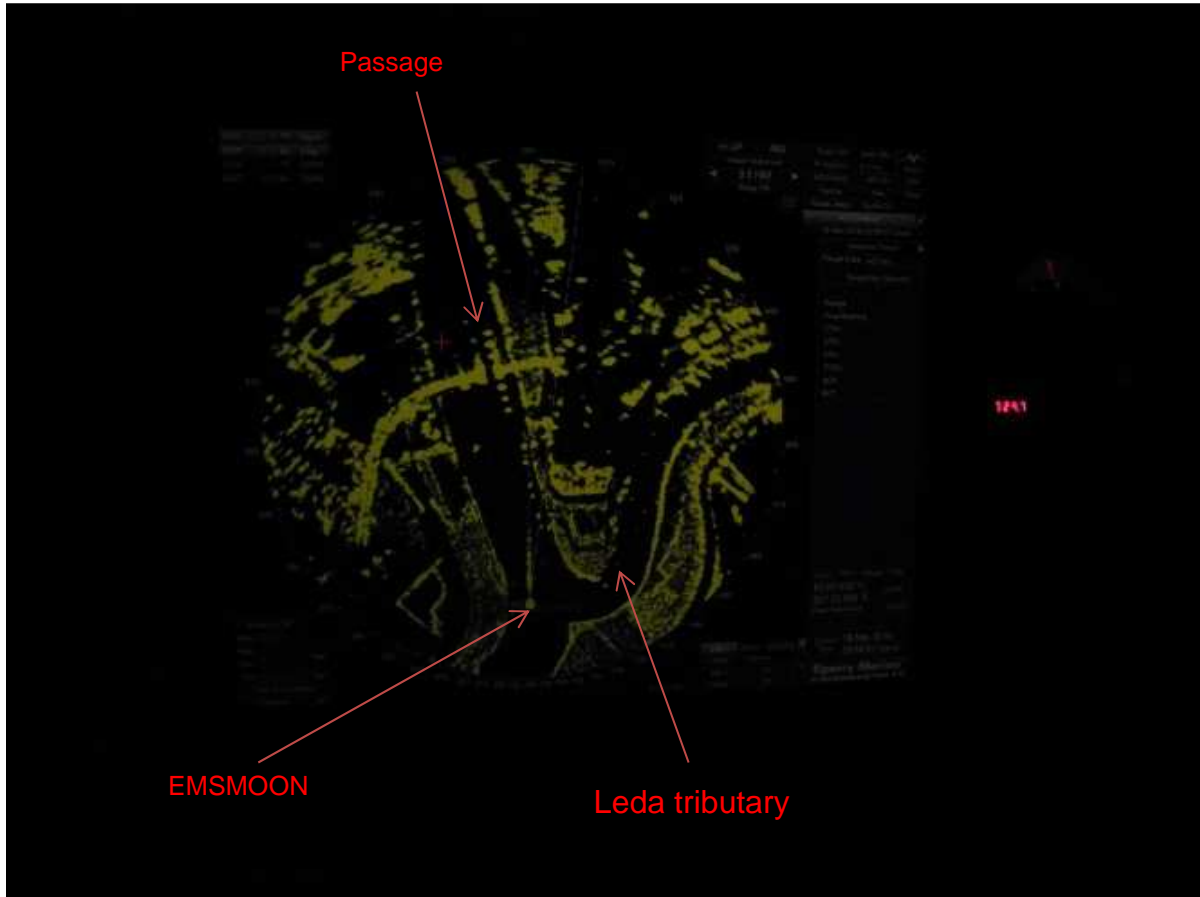


Figure 14: Range of 0.5 nm, Jann-Berghaus Bridge

With regard to the survey, it should be noted first that the factory lighting in the background also interferes with the new lights severely and the radar systems do not display the passages until relatively late. Furthermore, the ship's position in the fairway cannot be kept in an aft current.

3.2.7 Visit to the Emden pilot station

The radar images made during the survey on the EMSMOON and the signals and options for mooring between Papenburg and Emden were discussed with the Pilots' Association on 5 April 2016. The two bridge passages are only displayed clearly in a radar range of 0.25 nm – too late to be able to respond to them. Experience reportedly shows that only a continuous barrier is visible on most radar systems at Friesenbrücke Bridge, regardless of whether the bascule is open or closed. The options for mooring are only available to inland waterway vessels. They are not accessible to seagoing ships due to the shallow water depth. Furthermore, there are

no shore-based linesmen. The ship's position cannot be maintained in an aft current at less than 4 kts using a controllable pitch propeller and bow thruster alone. At best, it was possible to traverse toward one side. An additional stern thruster would be necessary otherwise. The bridge signals are virtually never paid attention to on the Papenburg-Emden section. Depending on visibility, they were reportedly inconspicuous or at Weener became evident too late.



Figure 15: Signal board on (photograph unknown)



Figure 16: Photograph taken at 1838 on 3 December 2015 (without signals)



Figure 17: Approach to Friesenbrücke Bridge (photograph taken at 0736 on 19 January 2016)

3.2.8 Survey of the scene of the accident on the FRIESLAND (Waterways and Shipping Office (WSA) Emden) on 5 April 2016

The agreement on the railway bridge between Deutsche Bahn AG (DB) and WSA Emden of 27 January 2004 was discussed. It indicated that the bridge would be open or closed for 30 minutes in each hour during the daytime under normal circumstances (if the duration of opening and closing the bascule is considered). The opening times are based on the hourly timetable, i.e. from Weener to Leer at 1823 and from Leer to Weener at 1838 in this case. A reporting procedure must be applied if 30 minutes are not met, which involves the bridge keeper advising the VTS of the opening. This exception is almost never applied. Accordingly, there was no requirement on the day of the accident, either. There is no procedure under normal circumstances.

Despite the fact that the signals on the bridge belong to Deutsche Bahn AG (DB), they comply with the standard of the Federal Waterways and Shipping Administration (WSV). A range is not specified.



Figure 18: Northerly passage with destroyed bascule and signal board

It was stated that waiting berths for large shipping can only be implemented on the stretch at great expense. Basins would have to be dredged continuously, which would then silt up again extremely quickly. Consequently, it is not possible to guarantee a maintained water depth along the dolphins. 1.5-2 million m³ of sediment

is dredged from the Lower Ems each year.³ The currents measured at the edges of Weener Bridge were about one knot on the day of the accident. According to information given by the pilots, it reaches up to 4 kts in the middle section of the Ems. It was agreed that the WSA would measure the current during a period of high water in the old passage. A longer section was not approved for measurement due to the ensuing obstructions. Ultimately, other methods were subsequently resorted to so as to obtain robust results.

The FRIESLAND was neither equipped with a log, which could measure the STW, nor with a river radar. The X-band radar system had an antenna length of 8 feet. The antenna length is important for the horizontal concentration. The antenna is located at a height of about 8 m above the water. Consequently, it was not possible to compare the radar systems with the EMSMOON and measure the current. Speed log measurements are reportedly inaccurate due to the river bed and shallow water depths. Viewed from the north, the passages of the Jann-Berghaus Bridge at Leer and the Friesenbrücke Bridge were displayed well on the radar system at a range of up to 0.5 nm. In the case of the Friesenbrücke Bridge, only the large passage is displayed at a distance of about 0.5 nm. The two passages are only clearly visible at the edge of the 0.25-nm radar range.



Figure 19: Jann-Berghaus Bridge, distance about 0.3 nm

³ In the opinion on the draft of this investigation report, the WSV and the Emden Pilots' Association provided the BSU with plans, photographs and CD surveys of the waiting berths at Mark North (western side of the Ems, km 6.2 at light post 140) and Mark South (western side of the Ems, km 5.8) dated 18 November 2015 (Mark N = 1.5 m, Mark S = 1.8 m), 4 December 2015 (Mark S = 2.4 m), and 10 December 2015 (Mark N = 3.4 m). Accordingly, based on the sounding chart valid on the date of the accident of 18 November 2015, the underkeel clearance at the waiting berths at Mark North (1.1 m) and Mark South (1.4 m) would have been sufficient. The structural approval of the waiting berths was conducted in May 2008 and they are suitable for inland and seagoing ships: For regionally operating large motor freighters, a length of 110 m, breadth of 11.4 m, load draught of up to 3.70 m (equivalent to a displacement of 4,000 t) and for seagoing ships that operate on the tide up to 8,000 t displacement, length of 120 m, breadth of up to 19.0 m, and draught of up to 6.20 m apply up to or from the sea lock at the port of Papenburg.



Figure 20: Jann-Berghaus Bridge, range of 0.5 nm

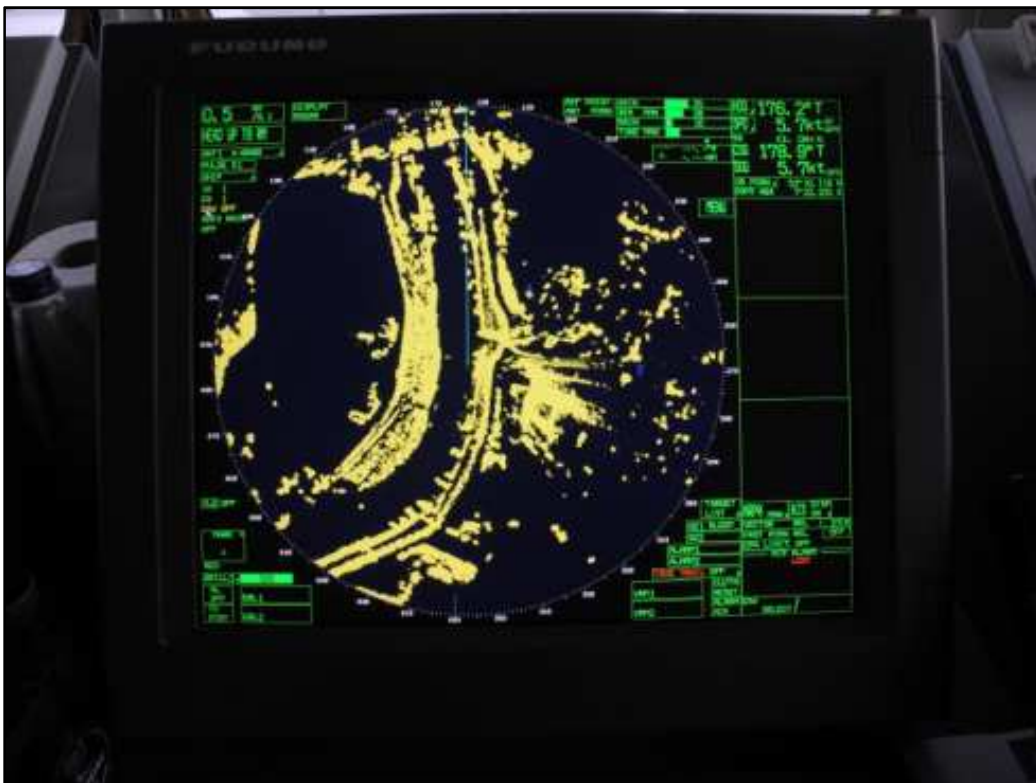


Figure 21: Friesenbrücke Bridge, range of 0.5 nm – large passage visible



Figure 22: Friesenbrücke Bridge, range of 0.25 nm – both passages visible

She stopped south of the Weener passage to watch the turn of the tide. There are no periods of slack water and the tidal curve rose steeply (measured in real time by remote data transmission).

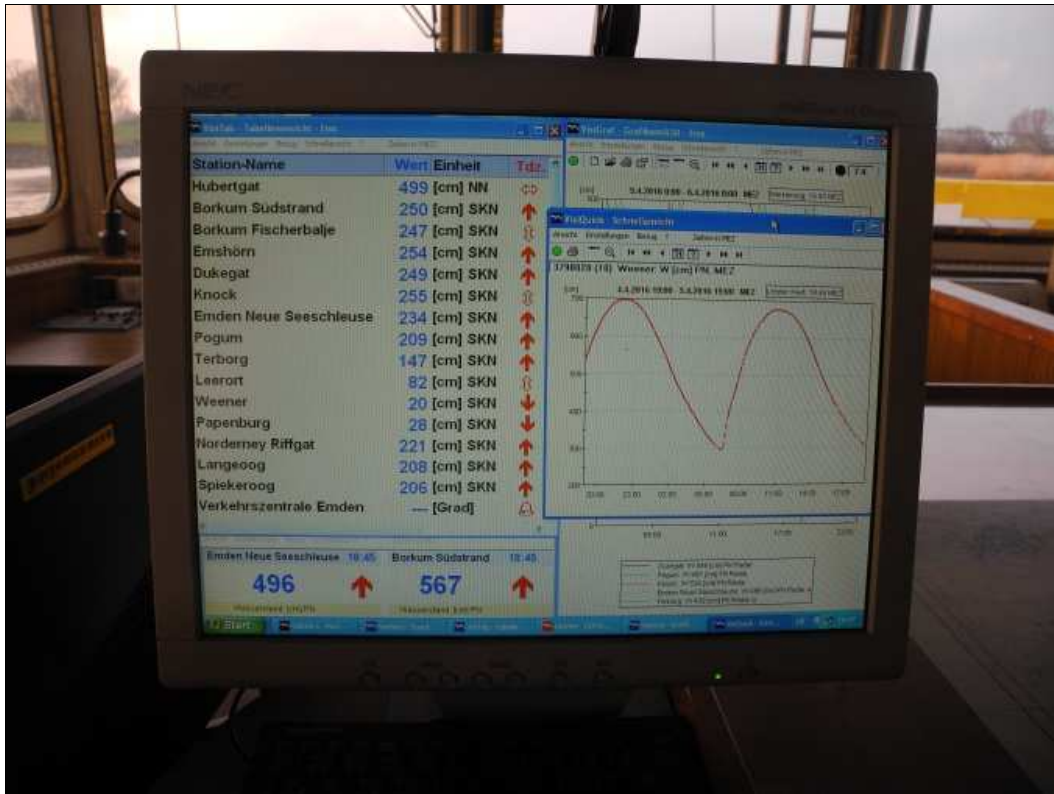


Figure 23: Ems water levels (real time)

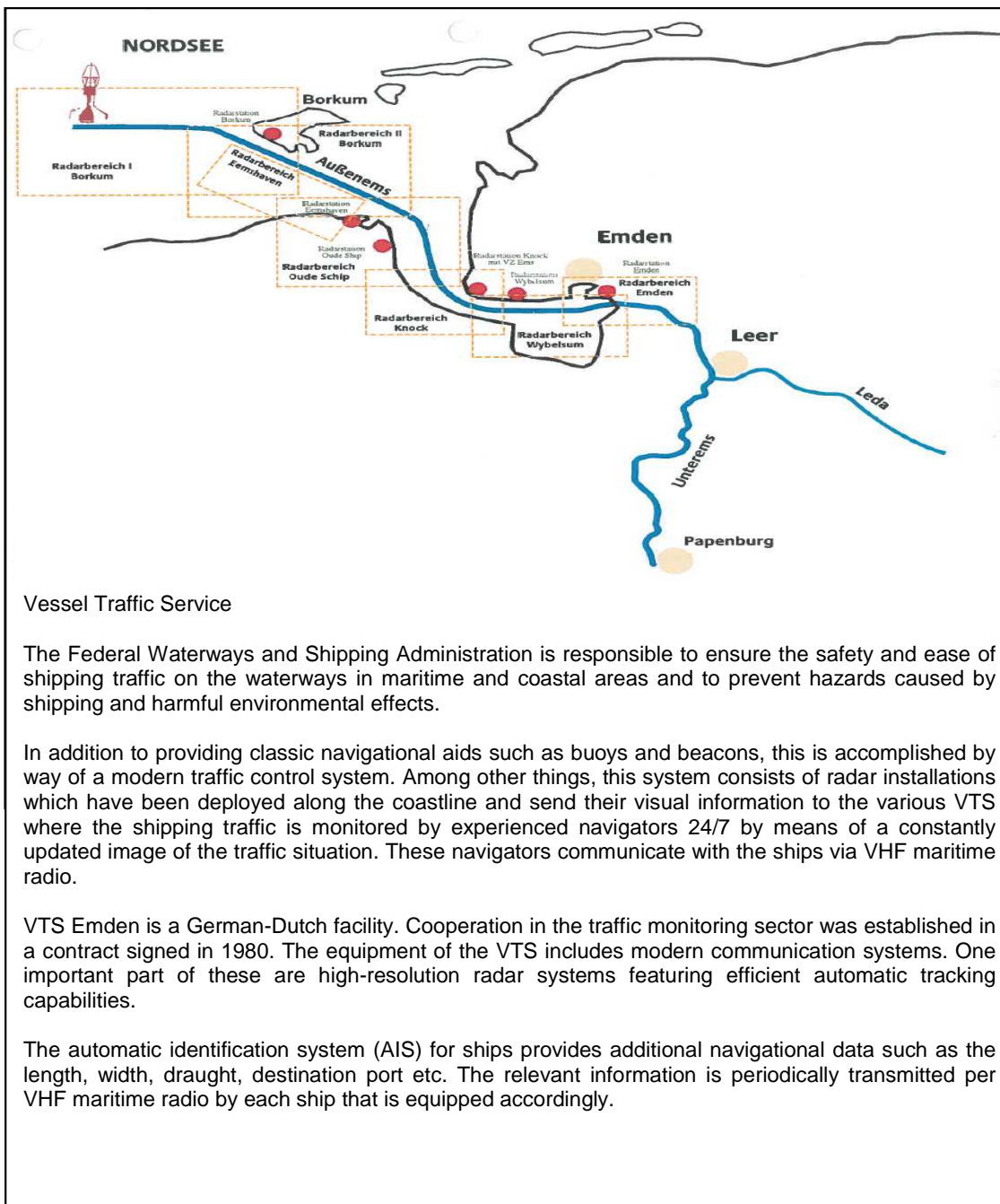


Figure 24: Piles for the shipping

3.2.9 Visit to VTS Emden by the BSU on 6 April 2016

VTS Emden (Ems Traffic) monitors the area from the Outer Ems to the Ems barrier in Gandersum depending on the physical range of the radar and AIS systems. Further upstream until Papenburg there is only radiotelephone coverage on VHF channels. AIS targets can be displayed on a simplified chart in this area. The bridges at Weener and Leer are not plotted in the chart.

Figure 25: German/Dutch VTS Emden



The BSH's VTS Guide Germany shows Ems Traffic's area of responsibility. Accordingly, Ems Traffic and Weener Bridge can be contacted on VHF channel 15.

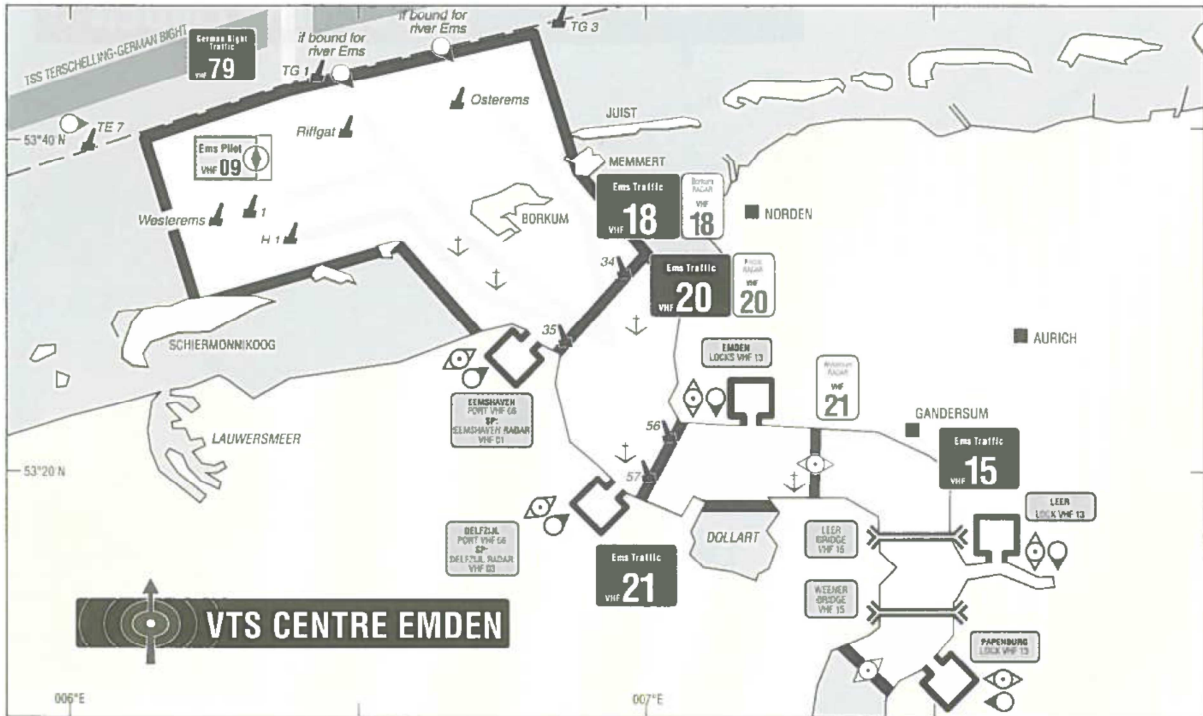


Figure 26: BSH No 2011, VTS Guide Germany (Ems Traffic)

The VTS has AIS and radar superimposition in real time, as well as automated alerting. Superimposition by two separate systems allows the verification of ship positions. The data sets of the vessels are retrievable.

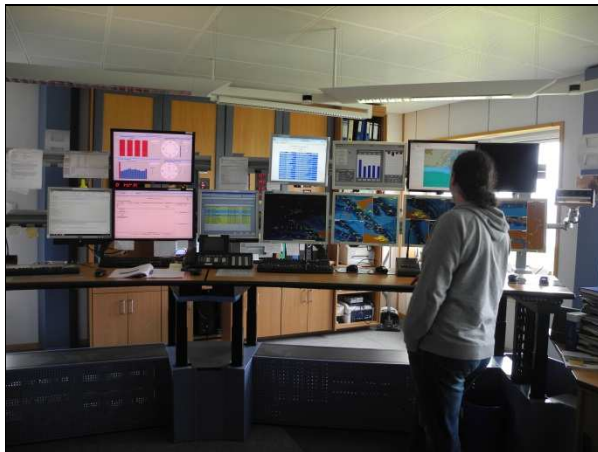


Figure 27: VTS Emden

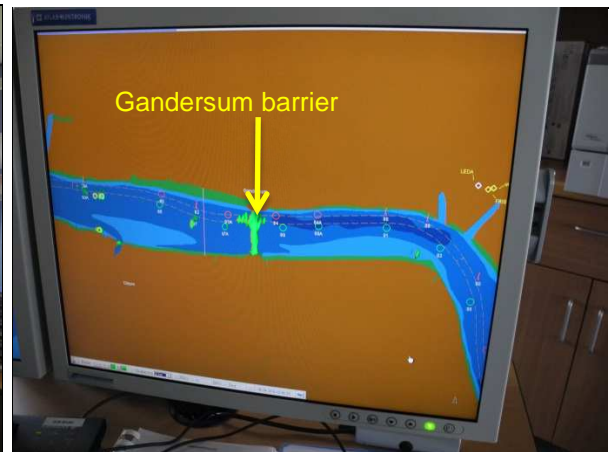


Figure 28: Gandersum (radar watch ends)

The status of the bridges at Leer and Weener are not recorded or known to the VTS, unless reported otherwise on VHF channel 15.

The WSA has no requirement to extend the area of surveillance up to Papenburg. About two seagoing ships sail to or from Papenburg each day. Reportedly, everything ran as it should up until the accident. There were reportedly no irregularities in terms of opening the bridge. When opening, it must also be taken into account that pedestrians cross the bridge. Agreements are said to exist with the district councils. No conclusions could be made as to the lighting on the pedestrian path.

It was emphasised that with the exception of the official notices, which pilots (amongst others) are required to take into account, the agreement between the WSV and DB does not have an external impact on pilots or others, for whom the Schifffahrtsordnung Ems (Ems Shipping Ordinance) and ensuing notices are authoritative. This states that the bridge is opened if necessary during breaks in railway operation and the bridge keeper can be contacted on VHF channel 15. The audible request signal to open the bridge (two long) is reportedly also available. Advance notice is required for the bridge to be opened between sunset and sunrise.

A reporting point is located at km 0 after leaving the lock in Papenburg. Amongst other things, the draught, crew and port of destination are reported to the VTS on VHF channel 15 there. Moreover, pilots contact the bridge keeper at the high-voltage power line before the final bend about 8 cbl before the railway bridge to coordinate the passage.

The signals on the bridge and VHF radiotelephone are the only options for controlling the traffic. It would be technically feasible to transmit the status of the bascule, e.g. via AIS, radar transponder, video broadcast, or permanently installed signal boards that transmit the status to the VTS. The installation of a distance signal, e.g. at the high-voltage power line, is another possibility.

A seagoing ship en route from Papenburg to Weener has no way of stopping and maintaining her position in an aft current. She is forced to organise her voyage so as to arrive when the bridge is open. At a SOG of 8 kts, it takes about 30 minutes to sail from the reporting point in Papenburg to Friesenbrücke Bridge.

3.2.10 Visit to the signal box at Friesenbrücke Bridge by the BSU on 6 April 2016

The BSU's task was explained and both the accident and the agreement between the DB and WSV were discussed. The DB's signalling technology was described. It is an analogue system. The signals must be set manually. The light signals can only be set when the bascule is open or closed. An alarm is issued if a signal fails. The bridge keeper could stop the train approaching from Weener using the distance signal. It is located 700 m from the bridge opening and operates by means of contact switches, which can also stop the train automatically. This method is calculated for a speed of 100 km/h.

The bridge keeper is equipped with a VHF radiotelephone and binoculars. When the EMSMOON passed the bend after the high-voltage power line, he had six minutes available to stop the train to Leer. It is important to remember that he had to estimate the speed of the EMSMOON visually by means of the navigation lamps alone. The bridge keeper's role in relation to shipping is to open the bridge. Apart from exceptions in the agreement, there are no procedural instructions for this.



Figure 29: Signal controls



Figure 30: Bridge monitoring console

Plans to rebuild the railway bridge are in place because it forms part of the European network. Agreement with pedestrian traffic could only be made orally, i.e. a check as to whether any pedestrian is between the barriers must be made before opening.

4 ANALYSIS

4.1 S-VDR analysis

The audio recordings were of unsatisfactory quality and technically enhanced by the Federal Bureau of Aircraft Accident Investigation. WSP Emden sent the BSU a transcript of the audible passages. This essentially concerns the VHF calls with Ems Traffic, Weener Bridge and Leer Bridge. The radar images relate only to the 0.25-nm range (off-centre), meaning only to the three minutes leading up to the collision in which the Friesenbrücke Bridge can be displayed. The speed is displayed by DGPS receiver and refers to SOG.

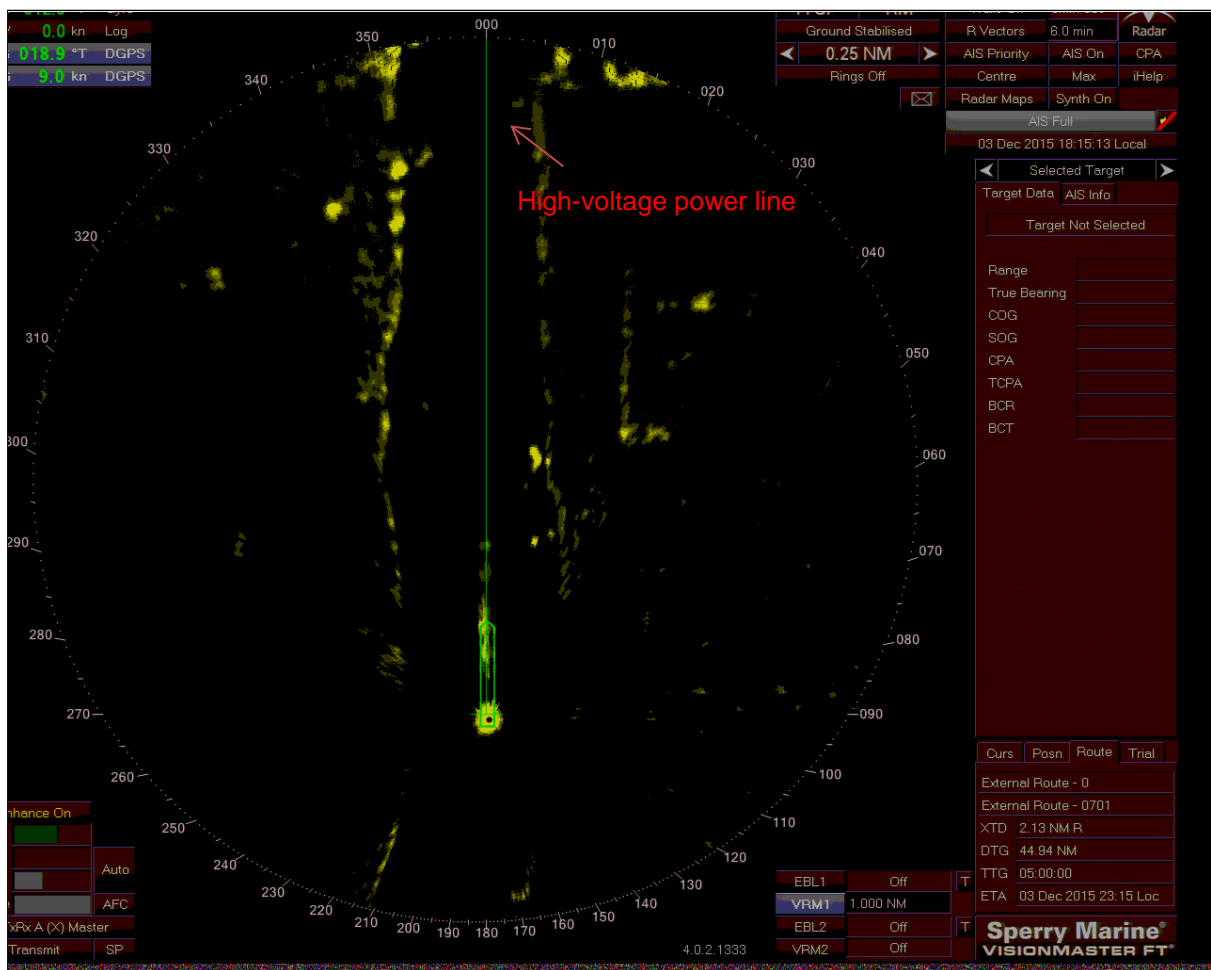


Figure 31: Before the high-voltage power line at 181513 (9 kts)

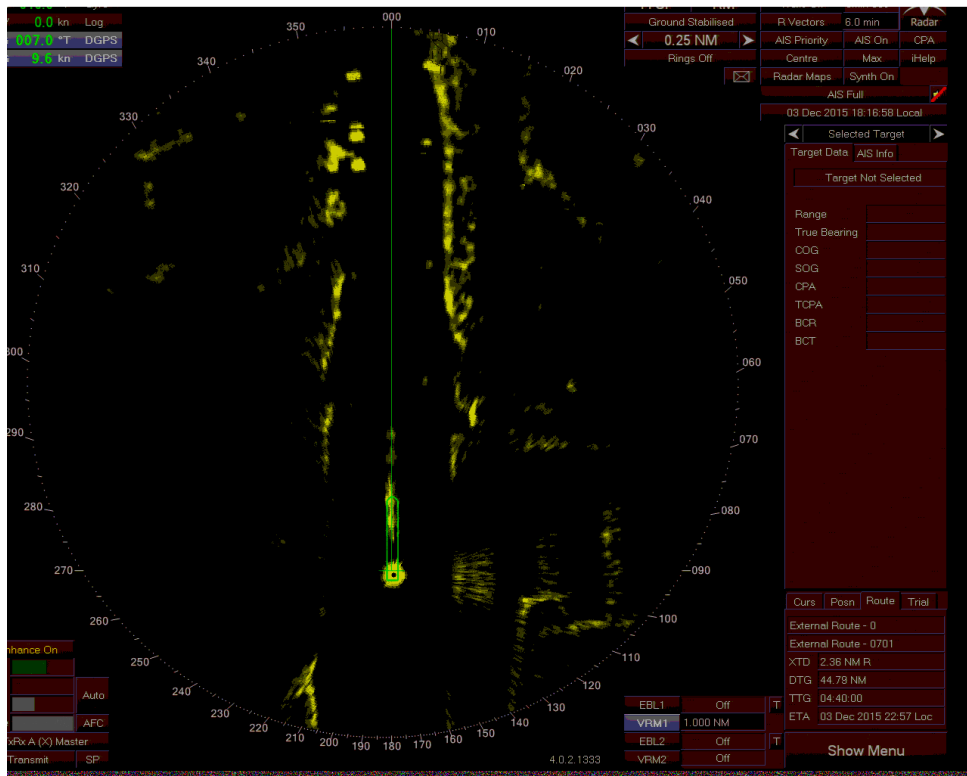


Figure 32: Beneath the high-voltage power line at 181658 (9.6 kts)

The diagonal high-voltage power line is visible for the first time at 181513. The EMSMOON is directly beneath the high-voltage power line at 181658.

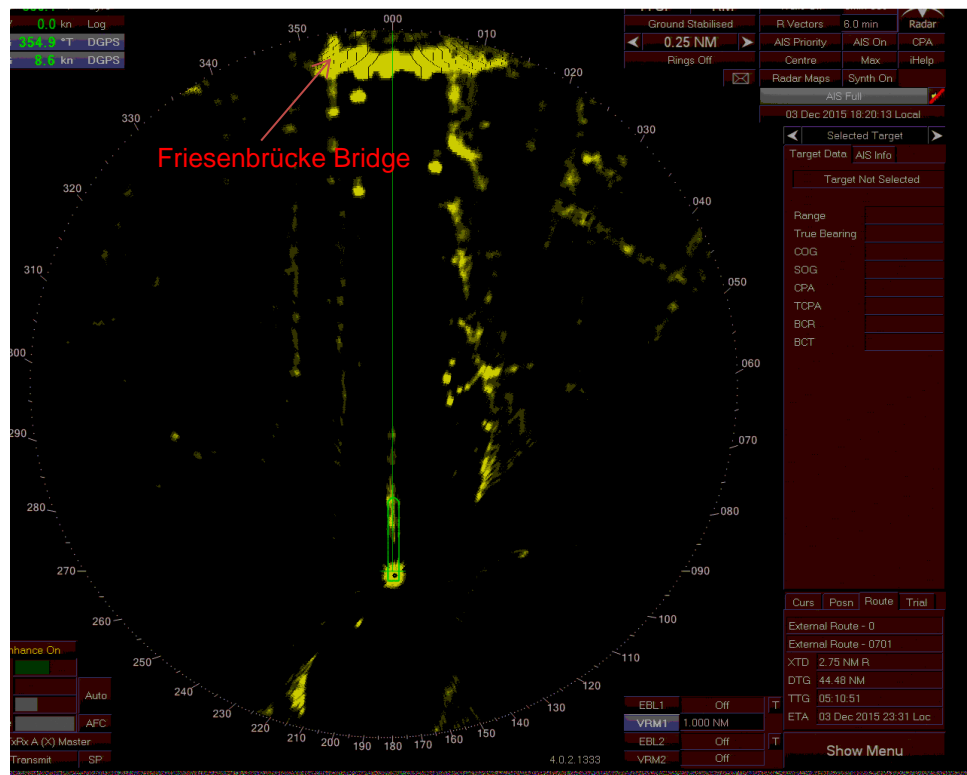


Figure 33: Friesenbrücke Bridge at 182013 (8.6 kts)

Ref.: 470/15

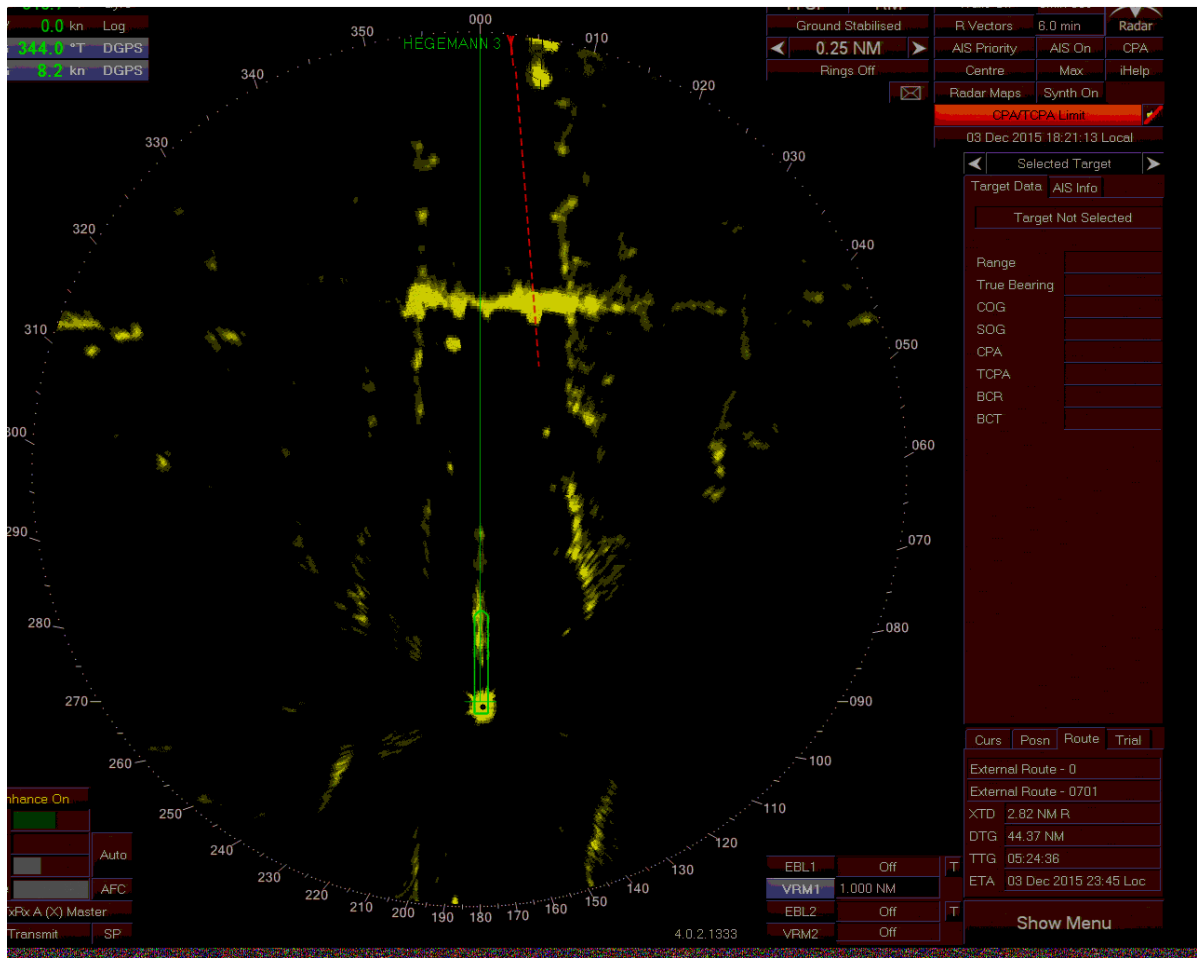


Figure 34: Friesenbrücke Bridge at 182113 (8.2 kts)

The Friesenbrücke Bridge is visible for the first time at 182013. The bascule bridge's passage can be surmised at 182113.

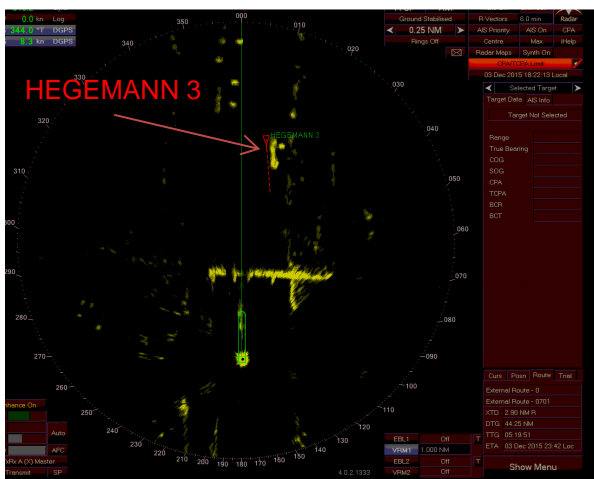


Figure 35: Friesenbrücke Bridge at 182213 (8.3 kts)

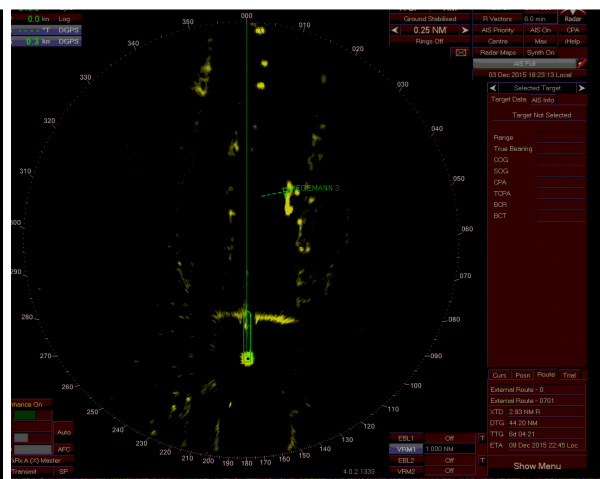


Figure 36: Friesenbrücke Bridge at 182313 (0.3 kts)

Two openings on the bridge can be seen at 182213 (one minute before the collision). The dredger HEGEMANN 3 is shown as an AIS target. The EMSMOON collides with the bascule bridge at 1823.

4.2 VTS and WSP analysis (audio, AIS)

VTS Emden provided the BSU with recordings of the VHF traffic and AIS. The BSU was also in possession of an AIS recording of the final minutes leading up to the collision from the WSP coordination centre.

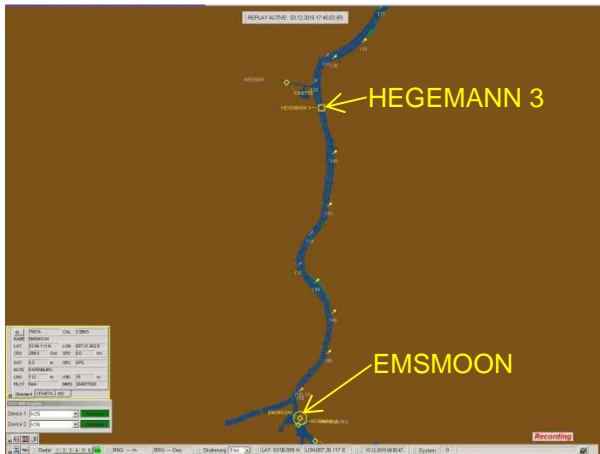


Figure 37: VTS at 174503
First message (lock)

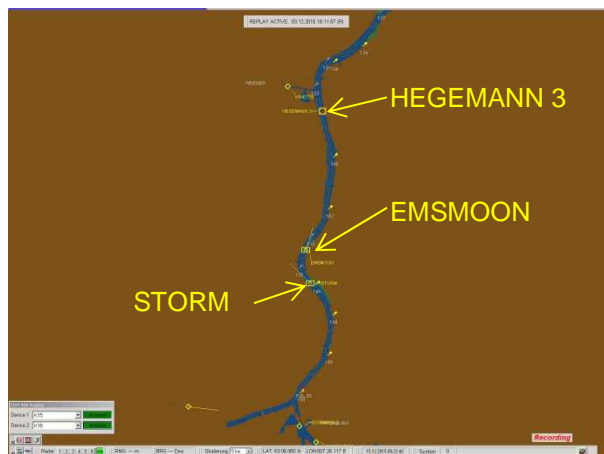


Figure 38: VTS at 181157
Second message (trains request)

No AIS signals are visible on the VTS's rudimentary AIS chart after the pilot's first report to Ems Traffic while proceeding to the Friesenbrücke Bridge. The dredger HEGEMANN 3 is located immediately behind the closed bridge at the berth on the right-hand bank. According to the rough VTS chart, the EMSMOON is located just south of beacon 135 about 8 cbl away from the high-voltage power line when the second report is made. The inland waterway tanker STORM is located at beacon 144 some 5.5 cbl behind the EMSMOON.

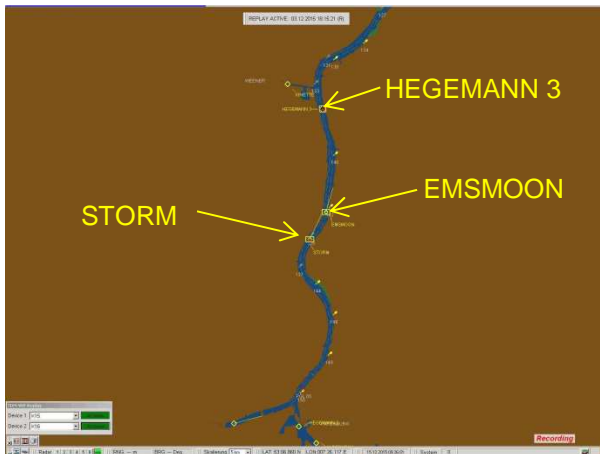


Figure 39: VTS at 181521 (third report),
3 cbl south of high-voltage power line



Figure 40: VTS at 181715,
high-voltage power line

The STORM is located 4 cbl astern when the EMSMOON makes the third report before and beneath the high-voltage power line.

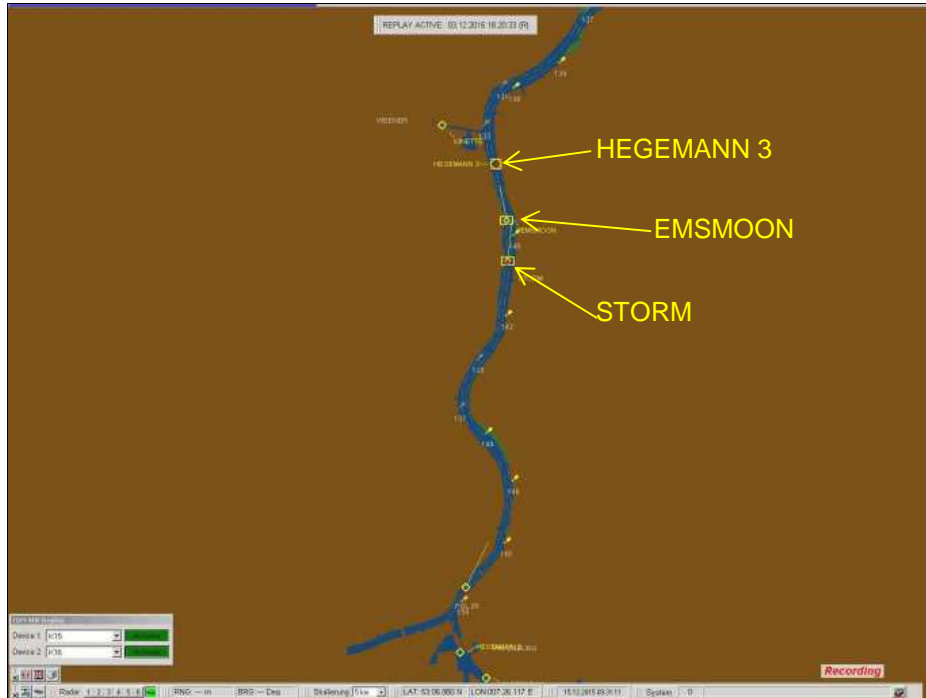


Figure 41: VTS at 182033 (fourth report to Leer Bridge)



Figure 42: VTS at 182309 (collision with Friesenbrücke Bridge)

The STORM is located 3.5 cbl astern when the EMSMOON makes the fourth report and only 2.5 cbl astern during the collision.

According to the audio recordings (transcript of the VHF maritime radio communications on channel 15), the radio communications shown below were carried out.

Evaluation Record

regarding recording of VHF maritime radio traffic on 03.12.2015

Start: 17:59:27 (time code on data carrier)

18:06:45

BMS Storm: *"Weener Bridge. Weener Bridge - ... (incomprehensible), good evening."*

18:06:57

Weener Bridge: *"Hey, in dire straits again?"*

BMS Storm: *"Yeah, yeah, I'm behind the 'Emsmoon'."*

Weener Bridge: *"Yeah, I don't know ... When do you want to get through? When will you be here?"*

BMS Storm: *"Don't know. I don't know what you are talking to him (incomprehensible) about. To the 'Emsmoon'."*

Weener Bridge: *"Yeah, right. Let me think. Ok, there's a train coming at 'twenty-three'. When it's passing through - by half past, ... "*

BMS Storm: *"Passing through twenty-three, yeah yeah yeah yeah. I don't know what you want, how much he's stepping on it."*

Weener Bridge: *"No, step on it a bit, ... Got a bit of power, after all."*

BMS Storm: *"All right, can do."*

18:07:33 End of Conversation

[Pause]

18:11:57

MS Emsmoon: *"Weener Bridge - 'Emsmoon'."*

Weener Bridge: *"Yes, Weener Bridge."*

MS Emsmoon: *"The next train due at twenty-three, right?! Twenty-three and thirty-eight for both trains, right?!"*

Weener Bridge: *"Yes, twenty-three - twenty-four the next one, and then until half past, right?"*

MS Emsmoon: *"Yeah, all right. We're now ... (incomprehensible), then (incomprehensible) ... I'll just come by, right?"*

Weener Bridge: *"Yeah, just come by. We'll soon see."*

MS Emsmoon: *"Yeah."*

18:07:33 End of Conversation

[Pause]

18:14:39

BMS Cybernetica: *"Ems Traffic for Cybernetica."*

Ems Traffic: *"'Cybernetica' - Ems Traffic. Good evening."*

[Pause]

18:14:57

BMS Cybernetica: *"Yes ... good evening. Papa Hotel seventy-four eighty-two (PH4782); empty vessel; draught one twenty; from Herbrum to Delfzijl; two people and two dogs."*

Ems Traffic: *"Yes ... the 'Cybernetica', one way from Herbrum to Delfzijl; empty vessel; two people; two dachshunds on board. We got all that. Have a safe journey and see you later."*

BMS Cybernetica: *"You bet. See you later. Have a good watch."*

18:15:15 End of Conversation

18:15:21

MS Emsmoon: *"Weener Bridge - 'Emsmoon'."*

Weener Bridge: *"Yes, 'Emsmoon' - Weener Bridge."*

MS Emsmoon: *"I'm at the high-voltage now. Should I hold my speed? We are going rather fast. Or should I slack off?"*

Weener Bridge: *"Yes, I've got the train. It's running three minutes late. It'll pass through around twenty-five, twenty-six. Then you can go through, ok."*

MS Emsmoon: *"Great, then I'll hold my speed, ok. Great."*

18:16:09 End of Conversation

[Pause]

18:18:27

BMS Storm: *"Weener Bridge - ... I'm five hundred meters behind, ok. Four hundred... five hundred ..."*

Weener Bridge: *"Yes, ... we'll soon see. You'll see. I think he'll be here in five minutes. Then I'll let him through. You go with him then."*

BMS Storm: *"Yeah, after all, I can't ... Then I'll have the Ems up in flames."*

Weener Bridge: *"Yeah - no. Can't do that, ... After all, you have to go back again."*

BMS Storm: *"Yeah ... see you later."*

18:19:03 End of Conversation

[Pause]

18:20:33

MS Emsmoon: *"Leer Bridge, Leer Bridge - 'Emsmoon'."*

Leer Bridge: *"'Emsmoon' - Leer Bridge, morning."*

MS Emsmoon: *"Morning ... yeah. Weener Bridge next, and then at your place in half an hour or so. Probably a little more, right."*

Leer Bridge: *"'Emsmoon', yes - km 13."*

MS Emsmoon: *"We'll do that. See you later."*

18:20:45 End of Conversation

[Pause]

18:21:57

Weener Bridge: *"'Emsmoon', you have to stop. The train isn't here yet."*

Weener Bridge: *"Hey, you've got to stop, the bridge is closed!"*

Weener Bridge: *"Emsmoon! Stop!"*

18:22:09

MS Emsmoon: *"Jesus, I though the bridge is open. ... Oh boy, we won't make it. There'll be a crash."*

Weener Bridge: *"I told you the train was late. It'll get here at twenty-five."*

MS Emsmoon: *"Jesus, I told you I'd hold my speed ..."*

18:22:33 End of Conversation

18:22:45

Ems Traffic: *"Storm' - Ems Traffic, did you get that?"*

Weener Bridge: *"Ems Traffic? Did you get that? The ship crashed into the bridge."*

Ems Traffic: *"Yes, I got it. The ship collided with the bridge. Any ... Probably some damage, I guess?"*

MS Emsmoon: *"Uh, Stefan, Emsmoon, uh... for Ems Traffic. Yes ... uh, the bridge is damaged. We are right in the middle of the bridge now. I assumed that, as agreed with the bridge operator, I could hold my speed. And uh ... I then approached, uh... the bridge with the corresponding speed. I hit he bridge... or we hit the bridge and... it's toast now."*

Ems Traffic: *"Yes, Joachim, I got that. Emsmoon - collision with the bridge. And, uh, yes ... of course, probably damage to the ship. Any ... any leaks or any injuries?"*

MS Emsmoon: *"No, no injuries. The bridge is, uh..., is..., yeah... the mid section is, uh... we hit it right on, the closed bridge. And, uh... I assumed it is open, uh... oh well..."*

Ems Traffic: *"All right, then we'll enter it in the log like this, uh. No injuries and uh, I assume that you'll first check if there are any hazardous materials leaking. Or if an oil tank or something like that is broken. Though in the front of the ship, yes ... and, well, we'll just have to see if we have to take any other steps. And, yes..."*

4.3 AIS analysis by the WSP

The distances to the Friesenbrücke Bridge and the SOGs were verified using the radar images from the S-VDR. Due to the time differences and varying measurement methods, the distances were specified only in cbl based on the position of the ship's antennas. There were SOG differences of up to one knot.

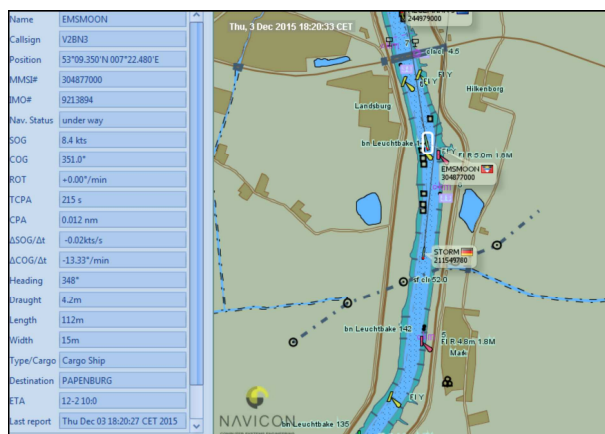


Figure 43: AIS at 182033 (8.4 kts, 3 cbl dist.)

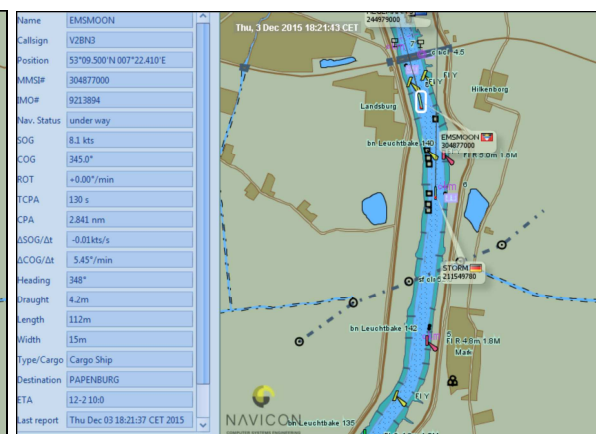


Figure 44: AIS at 182143 (8.1 kts, 2 cbl dist.)

Ref.: 470/15

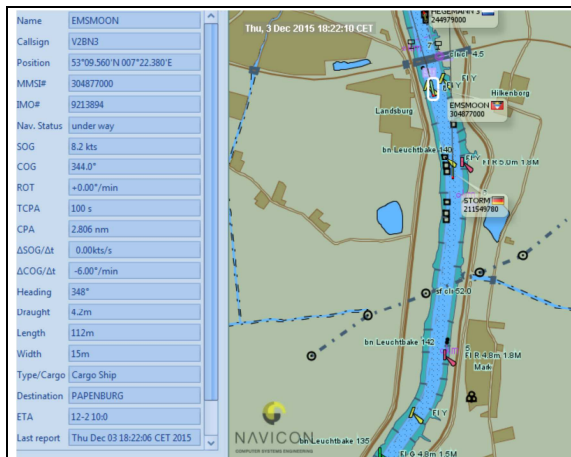


Figure 45: AIS at 182210 (8.2 kts, 1 cbl dist.)

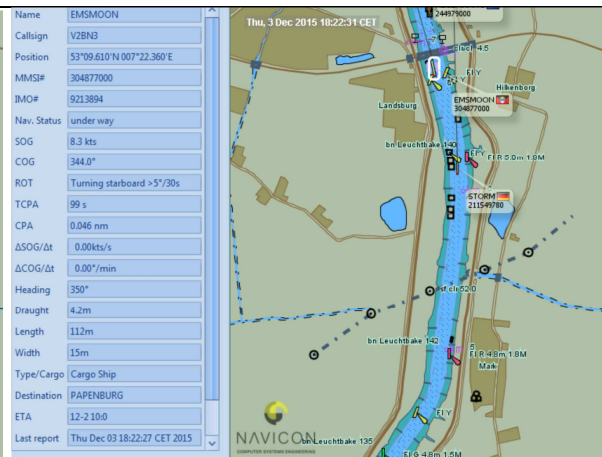


Figure 46: AIS at 182231 (8.3 kts)

The speed was barely reduced up until the impact with the Friesenbrücke Bridge. It drops rapidly due to the absorption of the lattice structure.



Figure 47: AIS at 182249 (6.6 kts)

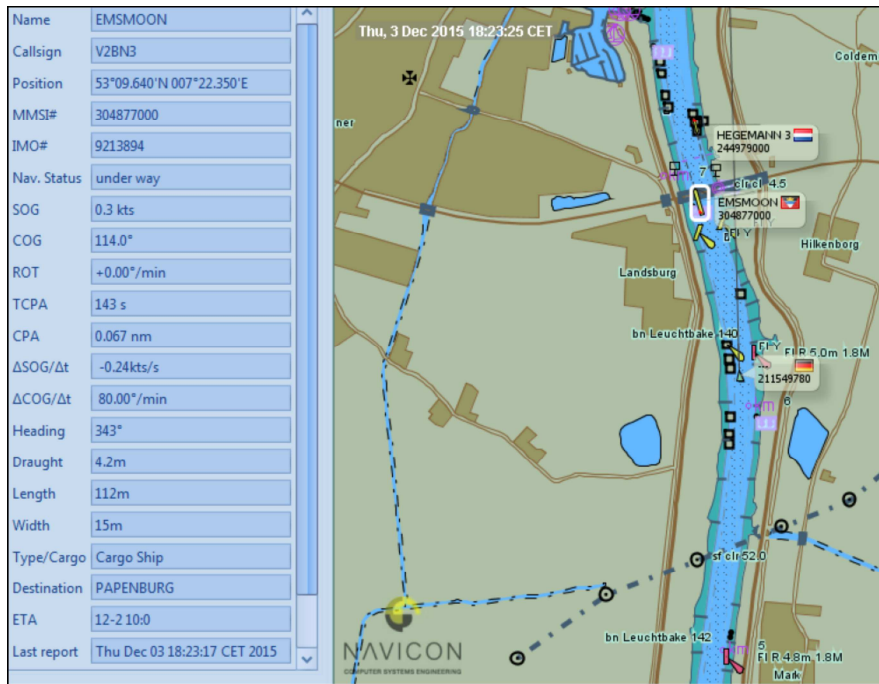


Figure 48: AIS at 182325 (0.3 kts)

4.4 Current and tidal data of WSA Emden

The current meters are located on both sides south of the Friesenbrücke Bridge on the edge of the fairway. Both meters delivered virtually the same value, meaning it is sufficient to map the western side. The accident occurred just over 30 minutes after high tide, but a glance at the water level, set and speed of the current reveals a calm and steady flow pattern. The current was setting at 350°. Its strength was about 0.8 kts at a water level of 4.1 m above chart datum (CD = mean sea level (5.00 m) – 2.10 m). The swing in the measured current velocities (and the water level) is probably the result of the hull stopping relatively abruptly.

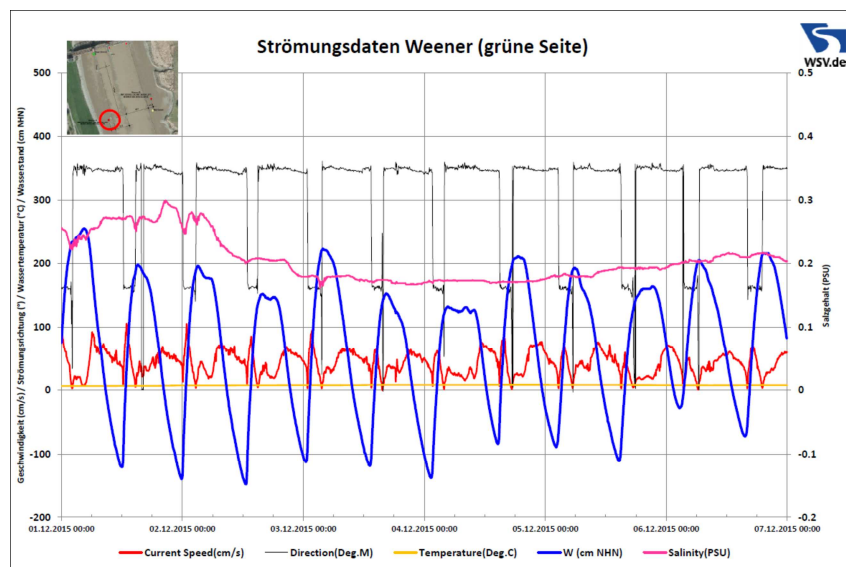


Figure 49: WSA Emden, weekly current data

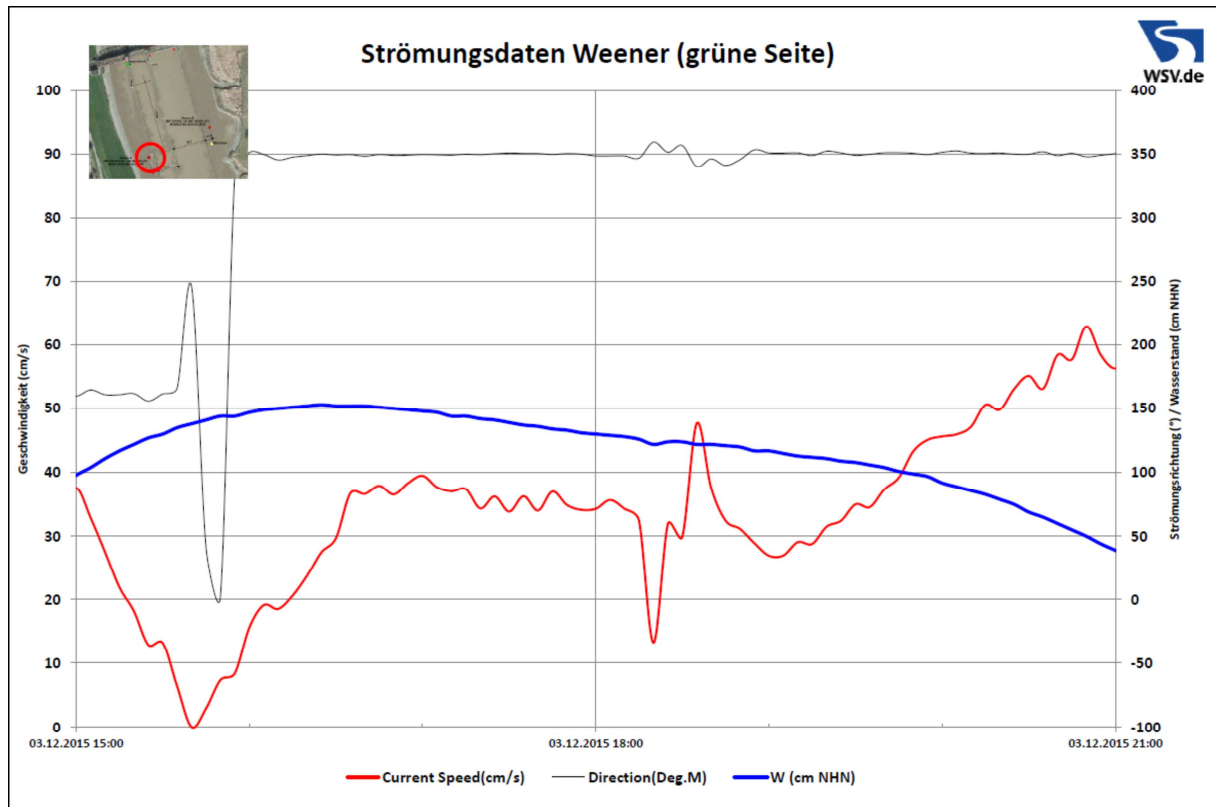


Figure 50: WSA Emden, current data at the time of the accident

4.5 Current measurements of WSA Ems

In the interest of the efficiency of traffic, the WSA chose not to act on the BSU's proposal to install a measuring buoy in the passage. Reliable and robust measurements take several months. In principle, the current velocity in the present section is not a fixed value. The speed varies based on time and locality, and depends on several factors. The tidal wave from the North Sea has the greatest influence in its relation to the parameters Earth/Sun/Moon and the meteorology. The significance of the upper water outflow, which affects the velocities in the area of Weener, is similar. The meters at Weener are installed outside the fairway in the interest of safety. To measure velocities inside the fairway, additional measurements must be made by a ship underway, so as to record the currents within the entire profile. The last ADCP⁴ measurements were taken by the Federal Waterways Engineering and Research Institute on 30 June 2015. With regard to timing, the velocity measurements are recorded properly using both test methods. The ADCP measurement of the flood tide stream was 1.5 m/s and long-term current measurement 1.2 m/s. The maximum velocity in the ebb tide stream rose to 0.75 m/s in the ADCP measurement and that of the long-term measurement to 0.8 m/s at the same time. The ebb tide stream was significantly lower and steadier. The maximum velocity variations are 0.3 m/s in the case of flood and 0.2 m/s in the case of ebb. A

⁴ ADCP: Acoustic Doppler Current Profiler. The low upper water outflows during the summer months, in particular, give rise to a sharp increase in suspended matter in the water column, which in respect of the technology used means a limitation to the surface areas because the measurement method can no longer detect deeper areas. The surface velocities are greater than those of deeper areas.

surface outflow of 40 m³/s greater than that of the comparative measurement prevailed at the time of the accident, however. The difference between the two flow states is roughly the difference between flood and ebb in the measurement of 30 June 2015. This indicates that in terms of scale the side-area measurements should behave in a similar manner to those taken at the time of the flood tide stream on 30 June 2015. WSA Emden does not expect a difference of more than 25% between cross-section averaged ADCP and long-term current measurement at the edges of the fairway. Given the uncertainties in the measurements, including in respect of the measurement timings in the summer and in the winter at different sedimentation, uncertainties must be allowed for when extrapolating the current data to the green side of Weener into the fairway. Were we to disregard the short-term macroturbulence-induced local fluctuations, then the current velocities in the area of the fairway stand at less than or equal to 0.5 m/s, i.e. less than or equal to one knot. These figures are specified by WSA Emden for the time of the accident, as they are considered relevant to navigation. If the time/locality-induced fluctuations are mapped, then instead it must be concluded that in the Ems at the time of the accident the fairway-related mean current velocities of 0.5 m/s maximum can rise to 0.7 m/s (1.4 kts) maximum for short periods in extremely localised instances.

4.6 Time sheets

The watchkeeping plan must be consistent with the Seafarers' Hours of Work and the Manning of Ships Convention. The limits on hours of work are as follows: (a) maximum hours of work shall not exceed: (i) 14 hours in any 24-hour period; and (ii) 72 hours in any seven-day period; or (b) minimum hours of rest shall not be less than: (i) ten hours in any 24-hour period; and (ii) 77 hours in any seven-day period. Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours.

A three-watch system on a four-hourly cycle was exercised on the EMSMOON at sea and a two-watch system on a six-hourly cycle in port. The master assists in watchkeeping at sea. In the 72 hours prior, there were no irregularities in the times recorded by the crew on the time sheets. Accordingly, the hours of work and rest were adhered to. Spread across the month, the chief officer, second officer and the cook had carried out the most overtime at about 140 hours per month in a 40-hour week, as expected. In the month of December, there were eight days at sea, eight days at sea/in port, three days at sea or in the Kiel Canal, and 12 days in port.

4.7 Opinion of the BSH

4.7.1 Investigation of the lighting technology (Annex 1)

The signal boards used on the Friesenbrücke Bridge at Weener all had extremely moderate ranges, which could be rated sufficient when also taking into account glare and interference lighting.

The chromatic points (chromaticity diagrams) according to the CIE (International Commission on Illumination) of the signal lights are borderline. The red signal light deviates considerably from the IALA colour range in terms of its darkness, but is nonetheless clearly red.

The signal boards are visible from the last river bend at a distance of about 0.8 nm (high-voltage power line) before the bridge due to their luminous intensity. Due to their covers and the resulting small beam angles, only the visibility at close range (at a distance of less than 0.3 nm off the bridge) could have been limited.

According to the investigation of the lighting technology on the signal boards used on the Friesenbrücke Bridge at Weener, it can be concluded that the signal boards and thus the state of the railway bascule bridge must have been sufficiently visible from the water in the dark.

4.7.2 Investigation of the radar technology (Annex 2)

The radar system on board detected the bridge passage at a distance of 548 m \approx 0.296 nm (range selected 0.25 nm) but off-centre (maximum view option) or 652 m \approx 0.352 nm from the radar antenna. At a steady speed of 8.6 kts, only a time frame of 123 s remains until the collision with the bridge. Accordingly, the radar system was not suitable for identifying that the bridge was open. Given the short warning period, the speed of 8.6 kts cannot be regarded as safe while proceeding with the current in a narrow fairway.

The BSH recommends the following technical and operational measures to prevent similar collisions:

- **Transmission of information on AIS and display information on a navigation system**

The IMO made it possible to transmit passage closures by means of AIS with the 'Marine traffic signal', which forms part of its Application-Specific Messages (ASM) (see Annex 1, SN.1/Circ.289, section 8).

While it is possible for these ASMs to be shown on a visual display unit in principle, a modification of the associated navigation system is required. This means that the manufacturer of the navigation device would need to develop and implement a corresponding upgrade in the system.

Display on a PPU, which a pilot might be equipped with, appears to be more practicable, as they are acquired for and operated in the area.

➤ **Distance signal**

A visual signal at a defined distance from the bridge would be another method of transmitting information early.

➤ **Emergency mooring**

The technical failure of the structure or ship cannot be precluded for as long as it is also possible to proceed when the bridge is closed. Consequently, the establishment, preparation and maintenance of an emergency mooring would seem advisable to prevent further risks.

➤ **Establishment of a defined radio procedure with traffic monitoring**

The firm definition of radio communications (preferably in the maritime mobile band to prevent the need for additional equipment and because all relevant bodies are integrated) would enable the definition of a safer procedure.

However, it would be necessary to ensure that the approving body can issue shipping police orders so that the statements are binding in nature. The requirement for emergency mooring also applies here.

➤ **Lighting concept**

An optimum lighting concept with clear and highly-visible navigational signals combined with better illumination of the bridge structure (the bascule bridge, in particular) can help to illustrate the situation visually, so as to make the correct decision in respect of passing the bridge.

4.8 Weather report by Germany's National Meteorological Service (DWD)

The visibility levels specified in the report relate to the meteorological visibility. Night visibility is measured only by a few manned weather stations. The **meteorological visibility** is the maximum horizontal distance at which dark objects close to the ground with an apparent angle of visibility of 0.5 to 5 degrees can just be detected against a bright horizon sky (also with fog as the background). At the same time, it must be possible to identify the object unequivocally. **Night visibility** is the maximum horizontal distance at which the white light of punctiform light sources of moderate luminous intensity is visible in the dark. Meteorological visibility is the same as or less than night visibility, depending on weather conditions. It is thus closer to the actual visibility in darkness than night visibility, as there is a strong dependence on ambient lighting at night. When estimating visibility in darkness it is also important to note that the eye must adjust to the low ambient brightness, which normally takes five to ten minutes.

4.8.1 Weather in the damage zone (Weener, Ems) at about 1723 UTC (extract from the DWD's official weather report of 27 June 2016)

Mean wind (at a height of 10 m above the water surface)/gusts:

Air stratification was humid and stable in the lower 1,500 metres (**Figure 52**), meaning the vertical momentum exchange was extremely weak in the absence of rainfall. Relative humidity stood at 100 per cent. The south-west wind between 500 and 1,000 m increased to 30-40 kts but penetration down to ground level was obstructed by a surface inversion at about 600 m (**Figure 52**). The current was not turbulent in the Leer area. Mean southerly winds of force 3-4 Bft (10-12 kts from about 190 degrees) prevailed at a height of 10 m at the time (**Figure 53**). There were no gusts of more than force 2 above the mean wind. However, gusts of up to 31 kts (force 7 Bft, **Figure 54**) were measured in the sea area. Corresponding wind warnings were issued for the coastal area.

Weather and visibility:

As can be seen in **Figure 52**, the air mass was humid up to strata at about 1,500 m. It was overcast and dry at the time of the accident (**Figure 51**). The cloud base stood at 4,700 feet with visibility of 20 km (**Figure 55**). The DWD had not issued any official onshore warnings for the period and region of relevance to the accident.

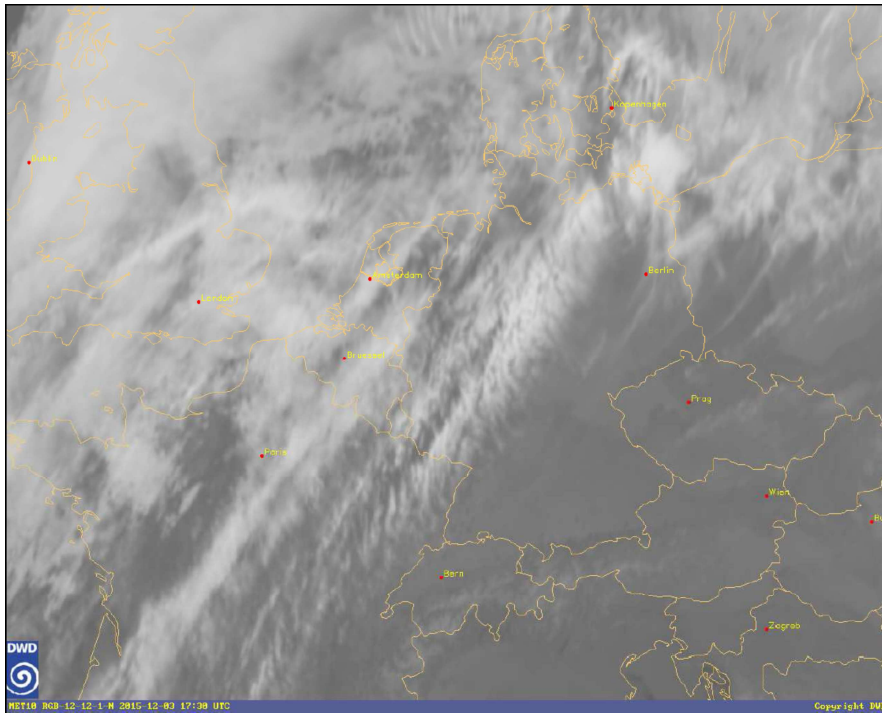


Figure 51: Satellite image showing cloud cover

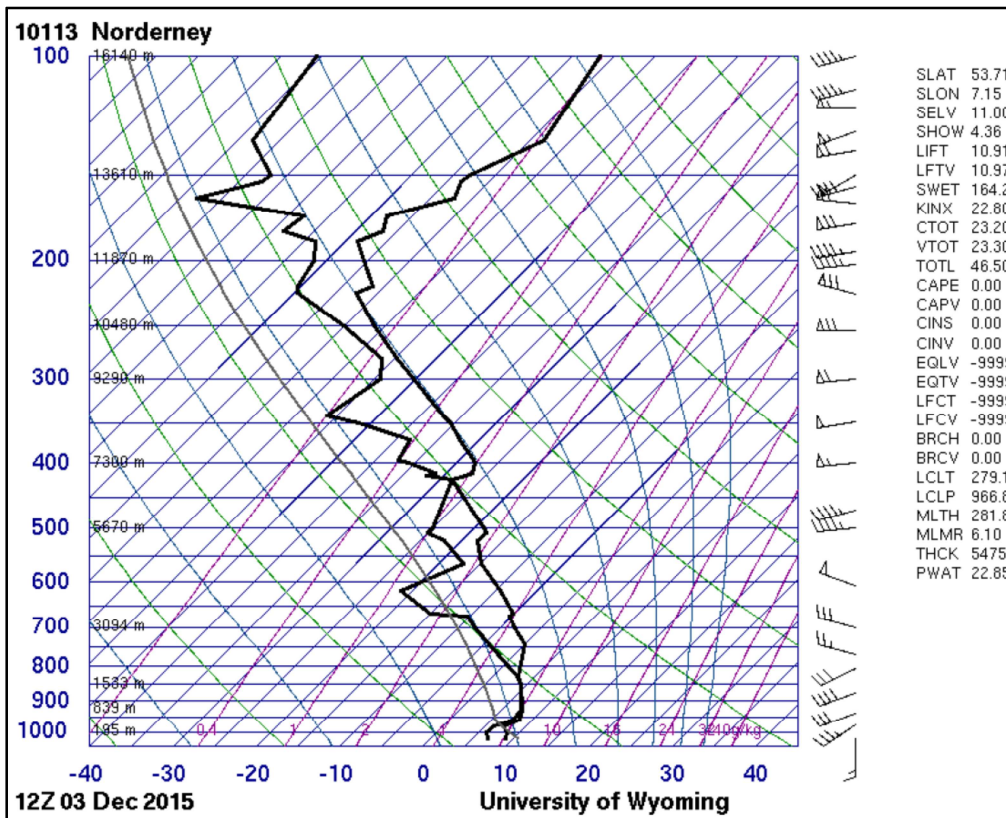


Figure 52: Relative humidity

The right-hand curve in **Figure 52** shows the temperature variation and height. The left-hand curve shows the vertical variation of the dew point. The relative humidity

stands at 100% at the point at which the two curves meet. The further apart the curves are, the drier the air. The further the temperature curve with height is inclined to the left, the more unstable the stratification. Air stratification is always extremely stable when the temperature curve is inclined to the right.

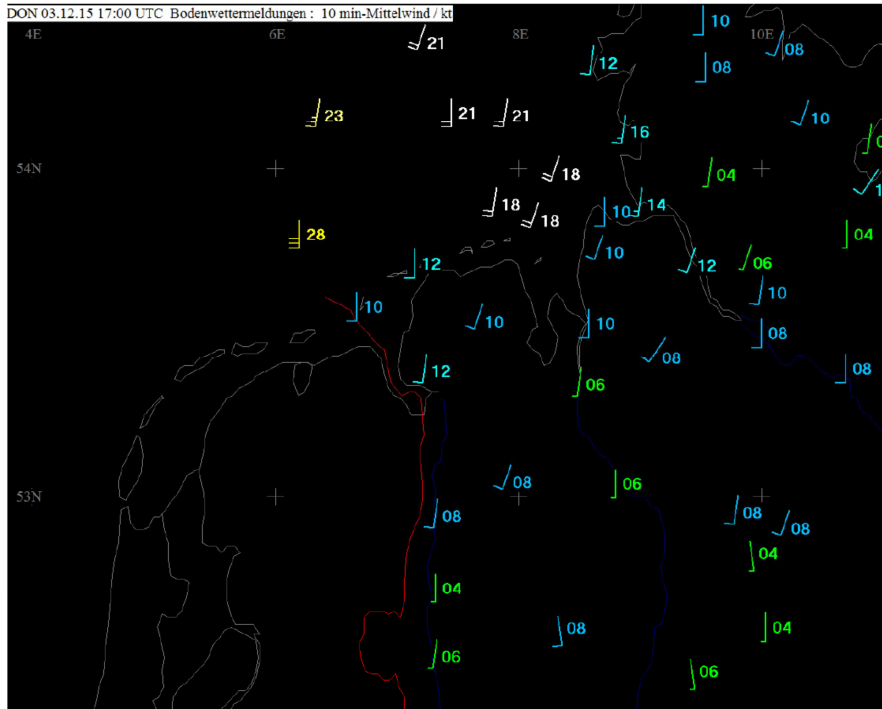


Figure 53: Ground report showing mean wind at 1700 UTC

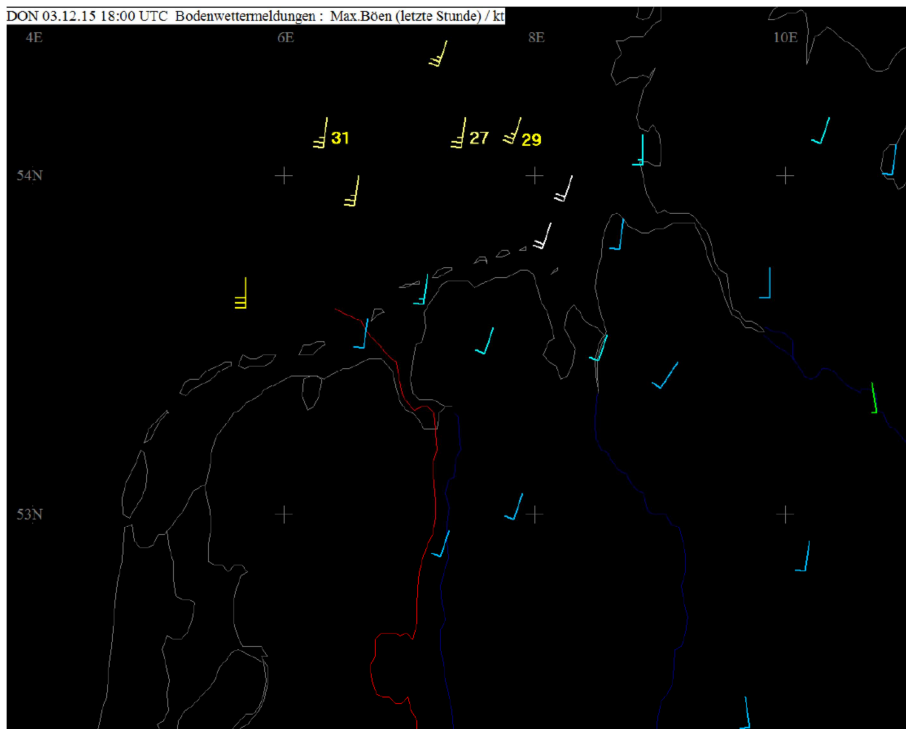


Figure 54: Ground report showing maximum gusts at 1800 UTC

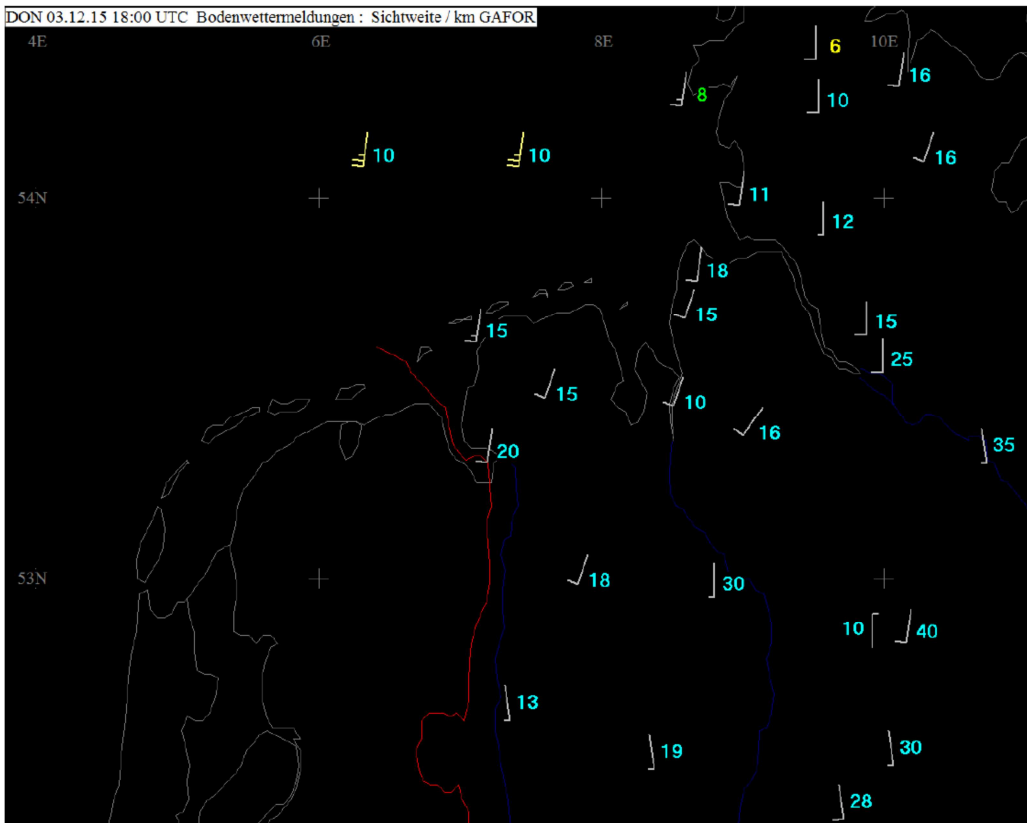


Figure 55: Ground report showing visibility at 1800 UTC

4.9 Signal box at Weener

As regards signalling, the signal box on the Friesenbrücke Bridge at Weener is independent of the railway stations at Weener and Ihrhove on the single line Ihrhove-Nieuweschanz track. The bascule's span is 29.1 m with a passage specified at 24 m in the navigational chart. The bascule can be opened up to 83° and is not illuminated. It takes about five minutes for the bascule to open or close in main operation at a wind pressure of 50 kg/m². The open bascule can be held in the locking system up to a wind speed of 20 m/s. The bascule can be opened or closed in about 12 minutes in auxiliary operation, e.g. using the emergency generator, if the main propulsion unit fails. Manual operation by up to six men using winding gear of four metres in length is also possible for servicing. It would then take about 100 minutes to open or close the bascule. The walkway on the bridge can be closed on both sides by a barrier. This is driven by an electric motor but can also be operated by hand. Overall control and monitoring of the bridge is carried out from the control console in the signal box. The status of the bascule, barriers and locking system (hold, open, closed), as well as the control lights of the points heating and bridge lighting are indicated by lamps. The lights can be checked using the lamp testing function.

Any movement can be initiated only after the preceding movement has finished. So-called 'bridge protective signals' are installed directly on and 700 m on either side of the bridge, which display a marker light in the bridge's default position (closed and locked) and when it is open.

The light signal system for shipping is used to control passages through the bascule bridge and beneath the bridge at a maximum height of 4.5 m, as indicated in the navigational chart. The 46-m wide fixed bridge opening in the middle of the stream is not defined. The Regulation on the Implementation of the Ems Estuary Shipping Ordinance (EmsSchEV) and the Notifications to Mariners of WSA Emden apply. Accordingly, two adjacent red signals with a white signal above (passage with due regard to oncoming traffic if it is clear that sufficient headroom exists) and the white illuminated bridge piers would have been visible on the EMSMOON if the bridge was closed. The requirements of the WSV (ADW No 4520) were observed in the configuration of the navigation signals. The navigation signals are released through floating contacts on the control console. When the bridge is fully opened, the keeper must switch the signal lever E-43-Stw so that the navigation signals change to two adjacent green signals with a white signal above (passage, observe oncoming traffic and right-of-way). If the bridge needs to be closed again, then the keeper switches the signal lever back 45° and the navigation signals change to two adjacent red signals. Once the bascule bridge is closed and locked, the signal pattern red/red with white above appears again. In the event of a fault, the emergency button must be operated and the navigation signals change to two adjacent red signals (bridge closed without limitation). The supervision lamp flashes if a signal lamp fails, thus alerting the keeper. The keeper must then change the signal lamp for the shipping immediately, otherwise the railway signals cannot be changed to proceed.

The bridge keeper can be reached on the DB's track telephony connection, on a public fixed-line connection, and on a VHF radiotelephony connection. A request to open the bridge can also be made by issuing the sound signal (two long blasts). The rail traffic between Ihrhove and Weener is controlled by train identification reporting system. The bridge keeper responds to the train reports of the traffic controller and records the rail traffic. The railway signals can only be switched to proceed after the bridge is closed, locked and the expansion joint has been checked mechanically and electrically. Management of the opening and closing of the bascule bridge is incumbent upon the traffic controller at Ihrhove.

5 CONCLUSIONS

A mutual misunderstanding of the radio communications between the bridge keeper and pilot on VHF channel 15 was responsible for the destruction of the closed bascule bridge at Weener (Friesenbrücke Bridge) by the EMSMOON. The pilot based his actions on the assumption of passing through an open bascule bridge prior to the announced train crossing. At the same time, the bridge keeper last announced at 181157 that the trains will run at 1823 and 1838 and confirmed that the EMSMOON could first approach. At 181521, the pilot reported in at the high-voltage power line, about 8 cbl before the bridge, and asked whether he should allow the EMSMOON to continue as before or slow down. The bridge keeper replied that the train was reportedly delayed by three minutes and would cross at 1825-1826, and the EMSMOON could then reportedly pass, to which the pilot replied that he will continue as before. At 182157, the bridge keeper warned the ship's command of the EMSMOON that she should stop and the bridge is still closed. The collision with the bascule bridge occurred immediately afterwards at 1823. Visibility stood at 20 km in southerly winds of 3-4 Bft. Despite that, the navigation signals at the bridge were not recognised in time.⁵ Behind the bridge they were interfered with by the bright lights and clouds of smoke of a factory on the port side, and the deck lighting of a dredger on the starboard side of the river. The bridge structure's floodlights severely interfered with the signal board on the starboard side of the passage.

Since the BSU is not in possession of testimony of the crew, it is only possible to surmise what led to the misunderstanding. The conversation between the bridge keeper and pilot was informal. Clear status messages were transmitted by neither ship nor shore. Instead of restricting his activities to advising the ship's command of the EMSMOON, the pilot conducted the radio communications with the VTS and bridge keeper, was at the helm personally and controlled the engine order telegraph (after all, no commands of the pilot could be heard on the audio recordings of the VDR). The presumed lookout and officer on watch were probably in the bridge wings to operate the searchlights for the illumination of sea marks on the Ems, while the master was possibly situated at the starboard radar system, which is located within reach of the engine order telegraph. The outcome of this situation was the pilot's inability to devote his full attention to monitoring the radio communications on VHF or the radar screens. He assumed the bridge was open and planned the passage of the Friesenbrücke Bridge accordingly. It was not possible to identify the signals displayed on the bridge or the bascule early enough on the ship in the darkness.

Radio communications were also misunderstood on inland waterway tanker STORM, sailing under pilotage. Based on the radio message recorded at 180657, the inland waterway vessel pilot (auxiliary skipper) assumed that she and the EMSMOON had seven minutes to pass the bascule bridge together. Consequently, she followed the EMSMOON in close proximity at a distance of 400-500 m.

⁵ The BSU is not aware of the use of binoculars.

The inland waterway vessel pilot concluded from the radio message at 181827 that the bridge would be open in five minutes, i.e. at 1823. It was not possible to recognise bridge signals on the STORM, as she was sailing in the shadow of the EMSMOON's illuminated superstructure.

The pilot sailing with the GERDA also made clear in his testimony that he understood there was a three-minute delay and the bascule bridge would be open for the EMSMOON. The GERDA passed the Friesenbrücke Bridge at 1700.

The EMSMOON's master left operating the controls and the radio communications to the pilot. Temporary assumption of responsibility for the controls on the bridge in different areas is consistent with current practice and goes beyond merely advising the ship's command. Steering by instruction is reportedly not always practical on the stretch between Papenburg and Emden, especially in darkness. Approaches to the embankments have confirmed this previously. Since the Ems does not have a continuous lighting system, operation of the helm and control of the pitch propeller by a navigator who is familiar with the area are pre-requisites for safe navigation. It is reportedly a matter of coping with the ship's rotational tendency. This is a question of the helmsman's intuitiveness. The slightest signs of pressure when approaching the embankment or a deceleration or unwieldiness of the ship must be monitored continuously and corrected. Moreover, the deep fairway is subject to a continuous process of change. Nevertheless, responsibility for the crew and ship remains with the master or officer on watch. He must always keep an overall view of dangerous situations. Here it is irrelevant whether the controls are operated via instructions and crew or the pilot directly. The master and officer on watch were unable to verify the radio communications because they were conducted in German. The pilot advised the master that the bridge was reportedly open, however. This misinformation led to a different assessment of the actual situation and possibly explains why the speed of about 8 kts remained unchanged.

There are no VHF maritime radio communication procedures between the bridge keepers and ship's commands, but bridge keepers are in possession of a VHF radiotelephony certificate. They do not have any shipping police powers like VTS Emden, however. Their main task is maritime traffic control, while the bridge keepers are responsible for setting railway signals and – in conjunction with opening and closing the bascule bridge – setting the navigation signals semi-automatically. Nevertheless, the bridge keepers are inevitably addressed by shipping not only with regard to bridge opening times, but also, as in the case in hand, with regard to navigation practices ("Yes, come up to us."). This is something of a predicament for the VTS, bridge keepers, and the ship's commands, as none of them are provided with uniform information, such as the current status of the bridge or the navigation/railway signal settings. This information can only be derived indirectly via the VHF radio communications.

The VTS does not keep a radar watch in the Ems navigable maritime waterway between Papenburg and the Gandersum barrier. AIS targets are simply displayed on a rudimentary chart, which does not have Friesenbrücke Bridge or Jann-Berghaus Bridge plotted on it. Monitoring actually only takes place via radio communications. This means that the VTS is not in a position to obtain a comprehensive picture of the traffic situation, nor is it able to perform its principal task of maritime traffic control in this area.

It takes about 30 minutes to cover the 4 nm stretch from the lock at Papenburg to the Friesenbrücke Bridge in an aft current. It was not possible for the EMSMOON to stop and keep her position with the left-hand controllable pitch propeller and bow thruster as the only means of propulsion. It is possible to traverse, however. This always involves moving forward in an aft current. The minimum manoeuvring speed of the EMSMOON is 3 kts. The bow thruster has no effect from 4 kts. She must proceed at a STW of at least 3 kts to preserve the ability to steer. The Doppler log displayed the current velocity on board. According to the performance standards, the Doppler log measures the STW from 3 m of water under the keel. This was roughly the depth of water under the keel of the EMSMOON, meaning it would have been reasonable to expect false measurements. On the port radar system, DGPS was configured as a speed sensor. The configuration of the starboard radar system is not known. When it analysed the course of the accident, the BSU only had the radar images for the final 13 minutes of the port radar system at a range of 0.25 nm available. This system's image and installation were criticised in the BSH's opinion. The BSU was not able to clarify who used which radar system and how they were used. When the BSU was on board, the port radar system displayed the Friesenbrücke Bridge's passages for the first time at between 0.25 nm and 0.30 nm. During the survey on the FRIESLAND, the radar system displayed the Jann-Berghaus Bridge at Leer and the Friesenbrücke Bridge clearly up to a range of 0.5 nm. The Friesenbrücke Bridge's two passages can only be seen clearly from the edge of the 0.25-nm range. According to information given by the pilots, only solid beams are often visible on both bridges when the passages are open. It should be remembered here that when switching the ranges on the radar it may be necessary to re-adjust the image to get a clear picture. The BSU was unable to determine the current velocity based on the S-VDR recordings. It was at least 2 kts according to the pilot. The lowest SOG without having to manoeuvre would then have been 5 kts. Based on the characteristics of the EMSMOON and the area with the varying currents, the BSU assesses the SOG of 8-9 kts at the bascule bridge as not too high, i.e. safe (in contrast to the BSH's opinion). In particular, the BSU was not able to clarify the velocity of the current when it interacted with the EMSMOON. The experience of pilots conflicts with measurements of WSA Emden, which presuppose an ebb tide stream of 1-1.4 kts maximum when uncertainties in the measurement procedures are considered and resulting fluctuations caused by macroturbulence ruled out.

There were only a few opportunities to vary the speeds and delay the time of arrival at the Friesenbrücke Bridge. At the specified three-minute delay of the train, a controlled grounding at an acute angle at the time of the message at 181521 at the high-voltage power line, some 8 cbl away, may still have prevented the collision with the closed bridge. Stopping in the fairway would not have been possible. An uncontrolled crash manoeuvre (full astern) in front of the bridge would have posed

the risk of broaching to and blocking the fairway, with the ensuing risk of following traffic not being able to make a controlled stop, either. At a duration of five minutes to open the bridge, there would have been no time for the EMSMOON to manoeuvre so that the passage ran smoothly even if the train had crossed on time at 1823. Consequently, the informal reporting point at the high-voltage power line would have been the EMSMOON's last opportunity for a controlled response without damaging the bridge.

Voyage planning using the procedures and technical equipment currently available is unreliable both on board and ashore and works only via the VHF radio communications, which turned out to be a substantial flaw in this accident. For example, about 3 cbl south of the high-voltage power line, the estimated time of arrival at the Friesenbrücke Bridge was 1818 according to the pilot.⁶ Regular traffic operation before the train crossing would not have been possible (without interfering with the train) even based on this incorrect assumption of the train being delayed for three minutes and an opening or closing time of the bascule of five minutes, as well as clearance for the train to proceed. A separate request for the bridge to be opened would have been necessary here. On the other hand, the WSV and DB Netz AG acknowledge in their agreement on the Friesenbrücke Bridge that such exceptions can only arise when the tide window falls to less than 30 minutes in a railway bridge opening interval which is too low for the shipping due to the timetable. The visual navigation signals on the Friesenbrücke Bridge alone are not a suitable means of enabling seagoing ships to identify the actual state of the bridge due to their visibility. During the voyage on the EMSMOON with the interested flag State Antigua & Barbuda, the open bascules on the Jann-Berghaus Bridge and the signals were only visible from the branch toward Leda at an approximate distance of 0.5 nm and the radars displayed the status of the two bridges only from a distance of about 0.25 nm, far too late for seagoing ships in tidal waters. On balance, the existing technology is not sufficient for planning the voyage on the Ems between Papenburg and the Gandersum barrier reliably or responding in good time to avert damage.

The BSH's opinion illustrated the constraints of the signalling and radar technology. It involved measuring the range of the signal lamps on the Friesenbrücke Bridge and analysing the EMSMOON's radar images. Due to their luminous intensity, the signal lamps are visible from the last river bend at a distance of about 0.8 nm (high-voltage power line) and the closed bridge was shown on the radar screen for the first time at a distance of 0.3 nm. The horizontal dispersion area of the light signals was 14-17° and they should have been visible over the entire width of the river from a distance of 0.3 nm. The lamp hoods (shields) were taken into account here.

⁶ The statements of the pilot differ from the times in the recorded audio logs by several minutes in some instances. According to the pilot's own testimony, his watch was slow by seven minutes (1808 instead of 1815) 3 cbl south of the high-voltage power line. The estimated time of arrival at the bridge differs by two minutes from the actual time of arrival (1818 and 1823 or a voyage time of ten minutes and eight minutes respectively). To that extent, they proceeded at a higher speed, which was caused either by an intentional increase or the current (2 kts measured at the ship) and wind (southerly winds of 3-4 Bft).

Eye-level on the EMSMOON at the bridge was 20 m and the signals were visible about 5 m above the water line at the time of the accident. The dike on each bank is about 10 m above mean sea level. There can be significant differences between the measured signal ranges and the signals actually seen from the bridge. The ranges shown in the navigational charts and the list of lights relate to the distance at which a light first causes a significant impression in the eye of the observer. Inter alia, the range depends on the luminous intensity of the light and the coefficient of atmospheric light transmission. The visibility of the signals is also affected by background and interference lighting. In this accident, the floodlights on the Friesenbrücke Bridge, the deck lighting of the HEGEMANN dredger, which was moored to starboard at the trestle just behind the bridge, and the lighting of the Klingele paper mill, which was behind the bridge on the port side, reduced the range of the signals, where the floodlights were located inside the direct field of vision of the EMSMOON and thus immediately reduced the range of the signal lights according to the diagram at Figure 2 of IALA Recommendation E-200-2 (Luminous range diagram – night time) to 1.4-2.6 nm. Other interference lighting was not considered in the BSH's opinion because according to the expert⁷ it was outside the field of vision immediately before the approach to the passage. A lighting concept consisting of clear and highly-visible signals with better illumination of the bridge structure could help to improve the situation on the bridge visually.

It was not possible to see the bridge signals on the ATLANTIC, a vessel that passed the Friesenbrücke Bridge in darkness on the morning of the day of the accident, either. It is likely that at the time of this observation the ATLANTIC was already within 0.3 nm of the bridge, where there was an upward shadow caused by the shields (hoods) within the signal board. In addition, a searchlight was directed at the passage and its glare probably concealed the lights on the signal board. The BSU therefore assumes that the signal board was intact.

The BSU finds that the signalling and lighting for Friesenbrücke and Jann-Berghaus Bridges are not satisfactory on the Ems navigable maritime waterway and basically endorses the recommendations made in the BSH's opinion. Larger vessels like the EMSMOON must be notified of the status of the bridge far earlier. The situation is in need of improvement through different technology both on board ships and ashore.

⁷ During the BSU's survey with the EMSMOON, observers on the bridge (see Figures 13 and 17) felt that the illuminated factory with its bright clouds of steam covered the Friesenbrücke Bridge's lattice structure from a distance and was definitely in the field of vision of the Friesenbrücke Bridge. Furthermore, the wing searchlights were also disruptive when they were directed at the signal board at the lock in Papenburg or the Jann-Berghaus Bridge. The signals were concealed by the glare and could no longer be differentiated. With her deck lighting turned on, the dredger HEGEMANN 3 was also a considerable source of interference lighting in the EMSMOON's field of vision if the searchlight shone in the direction of the EMSMOON. No technical measurements of the general light situation that prevailed on the day of the accident were made. Of significance is how the light situation is perceived by the observer.

Similar to the DB, distance signals could be installed ashore and the status of the Friesenbrücke and Jann-Berghaus Bridges transferred to the VTS electronically. On ships the PPUs could be used to transmit the status of the bridge additionally in real time. Reliable voyage planning would then be possible at least. In the event of complications in opening the bridge coupled with a ship in an aft current, using the new technology the ship could be grounded at an early stage or applying much expertise an attempt could be made to keep the ship at the existing waiting berths, such as Mark North and Mark South, in hazardous situations to avert greater damage. According to the sounding chart of 10 December 2015 provided to the BSU, which was created after the accident, the water depth at the Mark North waiting berth must have been 7.2 m. Having said that, the sounding charts valid at the time of the accident are of relevance to the pilots. They indicated that the water depth beneath the keel would have been 1.1 m or 1.4 m at the Mark North and Mark South waiting berths, although a maintained water depth cannot be guaranteed by the WSV. Mandatory traffic control by the VTS for the Friesenbrücke and Jann-Berghaus Bridge passages is also worth considering. Alternatively, voyages at night and in fog could be dispensed with, as was the case until 1985, or a second pilot could be tasked at night, so that the radiotelephone, radar systems and controls can be operated by someone familiar with the area. In particular, a second pilot would be necessary if he was requested specifically as a helmsman for longer distances.

The agreements between the former Waterways and Shipping Directorate North-West (Directorate-General for Waterways and Shipping (Aurich) since May 2013) of 2 June 1980 on the radiotelephony connection, as well as WSA Emden on the channel of communication for opening the Friesenbrücke Bridge for certain tide-dependent vessels sailing in either direction between Emden and Papenburg of 27 January 2004 with DB are not suitable for the smooth operation of the bridge and the safety and efficiency of vessel traffic. Amongst other things, the agreements do not entitle bridge keepers to issue instructions to shipping. The navigational signs displayed on the Friesenbrücke Bridge in accordance with the German Traffic Regulations for Navigable Maritime Waterways are of relevance to the control of vessel traffic. The radio messages exchanged merely facilitate better information sharing. The DB notes that as the operator of the railway infrastructure it must ensure a continuous transport chain and bases bridge opening times on the rail traffic timetable. At the same time, a regular sequence of bridge opening and closing slots, each with a duration of 30 minutes, must be ensured as a general rule. Transiting ships that are absolutely dependent on the tidal range may make a separate request for a bridge opening outside scheduled train intervals in exceptional cases (although this has reportedly never occurred). However, the bridge keeper actually intervenes in vessel traffic in that he sets the navigational signals and opens/closes the bridge. The VTS is only informed of that indirectly by listening in on the radio communications. There are no appropriate procedures arranged between DB and the WSV as to how vessel traffic should be controlled efficiently via radiotelephone, however. Consequently, as in the case in hand, the status of the bridge is not communicated. Keywords like 'Bridge closed' could attract attention in radio communications.

6 SAFETY RECOMMENDATIONS

6.1 Federal Waterways and Shipping Administration

The BSU recommends that the Directorate-General for Waterways and Shipping, as well as the Waterways and Shipping Office in Emden improve the safety and efficiency of vessel traffic on the Ems navigable maritime waterway between Papenburg and the Gandersum barrier by

1. replacing existing agreements between the owners, operators, and keepers of bridge structures on one hand and the Federal Waterways and Shipping Administration on the other with procedural instructions, which clearly provide that only VTS Emden may intervene in vessel traffic and which contain clear VHF radio communication procedures, including keywords on the status of a bridge and position of the navigational signals, inter alia;
2. implementing fixed signals at the edge of the fairway that indicate opening/closing times or closures and additionally for maritime shipping the transmission of bridge-related information to the PPU, which are used by pilots on the Ems, inter alia, as well as installing remote data transmission of the bridge signals at VTS Emden;
3. adapting the geographical information system in the VTS so that information on plotted structures, bridge signals, and vessels can be accessed and monitored in real time on a large-scale electronic chart and passages through a bridge can be managed with binding effect;
4. dredging waiting berths on an ongoing basis depending on the siltation and the depths required for the entire maritime shipping on the Ems between Papenburg and Emden, which safeguards the safety and efficiency of vessel traffic even in the event of obstructions or incidents;
5. publishing the ranges of the bridge and lock signals, taking into account interfering lights, and
6. improving bridge lighting so that the state of the bascules (open or closed) is visible from the river.

6.2 EMSMOON

The BSU recommends that the owners, operators and masters of the EMSMOON only leave operation of the helm and controls to the pilot for short periods when sailing between Emden and Papenburg in either direction and ensure that an officer is responsible for performing the navigational watch properly at all times for the purposes of the pilotage.

6.3 Ems pilots

The BSU recommends that pilots abstain from operating communication equipment and controls on ships fully independently when sailing between Emden and Papenburg in either direction, so that their full attention is devoted to the area of operation on the Ems. In particular, the helm, radar image observation and radio communications should not be performed by one person at the same time. If necessary, a second pilot must be requested in special circumstances and depending on the bridge design.

7 SOURCES

- Investigations of WSP Emden
- Written explanations/submissions
 - Emden Pilots' Association
 - WSA Emden
 - Owner
 - Deutsche Bahn AG
- Witness testimony
Pilots
- Reports and technical paper
 - Navigational charts and ship particulars, BSH
 - Jörg Kaufmann, Doreen Thoma, Hans-Karl von Arnim, Stefan Ruff, opinion on lighting and radar technology, BSH
 - Antigua & Barbuda W.I. Department of Marine Services and Merchant Shipping Inspection and Investigation Division, Bremerhaven
 - Dr Martin Krebs, WSA Emden, Hydrology
- Official weather report of the DWD
- Radar and audio recordings of VTS Emden

8 ANNEXES

Opinion on lighting and radar, BSH



Bundesrepublik Deutschland
Federal Republic of Germany

Bundesamt für Seeschifffahrt und Hydrographie
Federal Maritime and Hydrographic Agency



Technical investigation of light signals
(Friesenbrücke Bridge at Weener, Weener/Ems),
Marine Casualty Investigation 470/15

Subject: **Siemens dual-element lighting units**

Type designation: **8978/23a**

Report number: **BSH 4533/000/ 3058/16**

Contracting body: **Federal Bureau of Maritime Casualty
Investigation
Bernhard-Nocht-Str. 78
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Hamburg, 26 September 2016

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1 Introduction

The Friesenbrücke Bridge at Weener has a bridge segment that can be opened for the passage of large ships. At 1823 on the evening of 3 December 2015, a cargo ship (the EMSMOON) rammed the segment of the bridge that could be opened when it was in a closed state and destroyed it beyond repair.

The railway bridge's signal lighting is implemented by a number of signal boards belonging to Deutsche Bahn. Signal lamps (type 1230 (220 mA 30 W)) of 12 V (day operation) and 7.4 V (night operation) have been used.

Several floodlights have been used to illuminate the bridge.

Moreover, the Klingele paper mill in the immediate vicinity and an illuminated dredger at the edge of the river form part of the lighting in the background (interference lighting at night).

This report examines the visibility of the light signals on the Friesenbrücke Bridge at Weener.

2 Investigation of the lighting technology on the signal boards

The photometric examination of the original signal lights on Friesenbrücke Bridge at Weener was conducted in the BSH's photometric laboratory. The signal lights are dual-element lighting units made by Siemens and equipped with type 1230 (220 mA 30 W) signal lamps as light sources (Figure 72:). The luminous intensity to the horizontal dispersion angle in several intersecting planes and the chromatic points at various dispersion angles were measured.

2.1 Luminous intensity distribution curves (12 V day and 7.4 V night)

The measurements showed that the signal lights used have an extremely high luminous intensity and thus an enormous theoretical range of more than 6 nm. At approximately 14° to 17°, the horizontal dispersion area is relatively low, however. Nevertheless, we can assume that the signals are visible over the entire width of the river from a distance of 0.3 nm. At smaller distances from the bridge, the near-field of the signal boards would have to be examined more carefully, but this is not relevant to the accident under investigation.

2.1.1 White 12 V

The white signal light has a beam angle of 17.8° and a range of 1.0 nm during daylight hours.

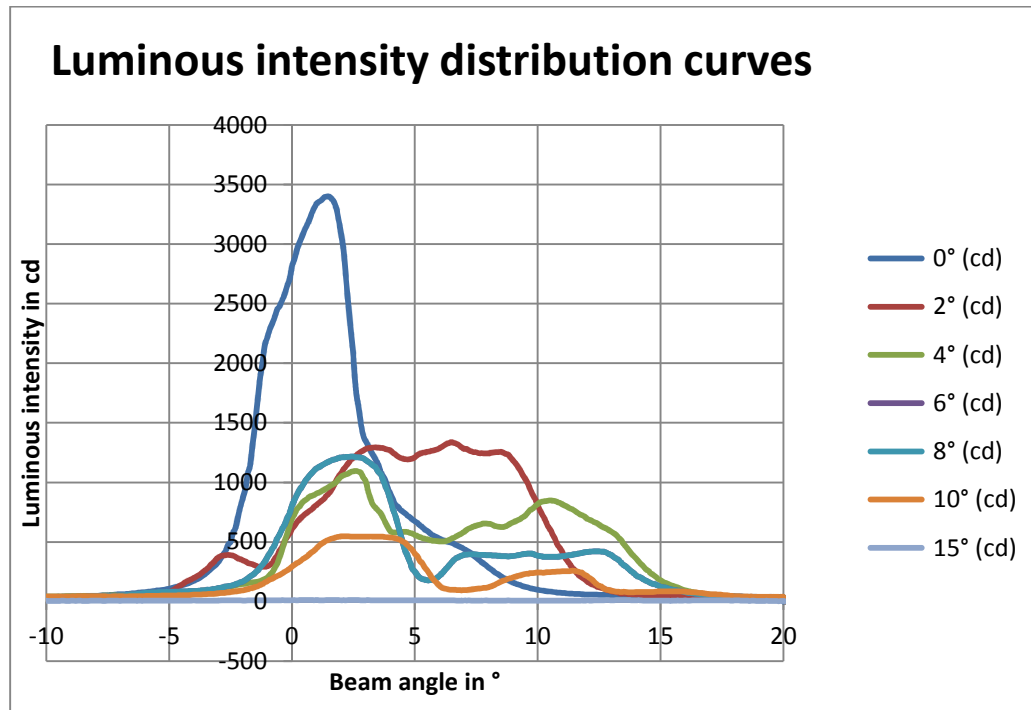


Figure 56: Luminous intensity distribution curves of white signal light during the day

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	2814 cd	2.1°
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	1407 cd	4.4°
$I_{\text{FTM}} 0.1 \cdot I_{\max}$	281.4 cd	17.8°
Maximum range	1.0 nm	

2.1.2 Red 12 V

The red signal light has a beam angle of 15.2° and a range of less than 1.0 nm during daylight hours.

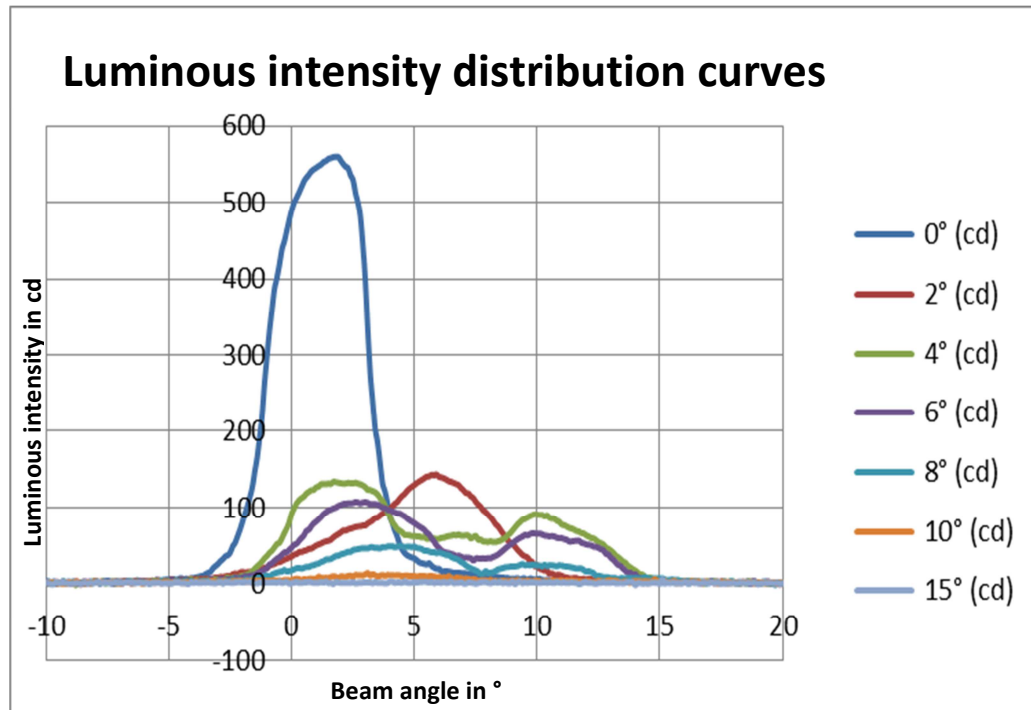


Figure 57: Luminous intensity distribution curves of red signal light during the day

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	490 cd	2.7 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	245 cd	4.4 °
$I_{\text{FWTM}} 0.1 \cdot I_{\max}$	49 cd	15.2 °
Maximum range	<1.0 nm	

2.1.3 Green 12 V

The green signal light has a beam angle of 15.1° and a maximum range of 1.0 nm during daylight hours.

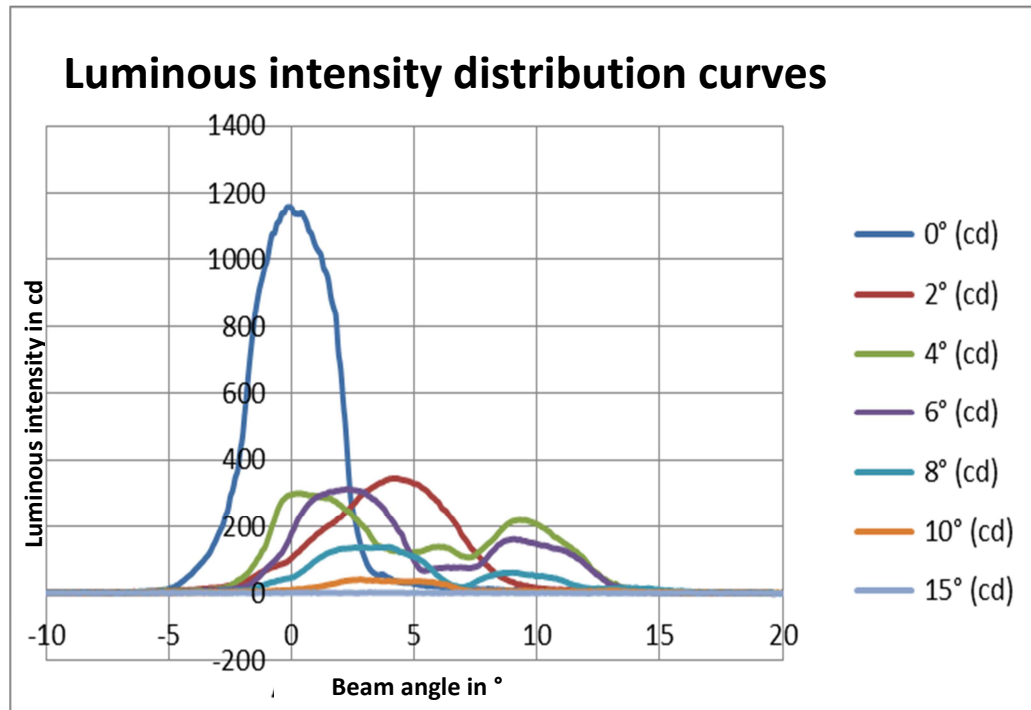


Figure 58: Luminous intensity distribution curves of green signal light during the day

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	1154 cd	0.2 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	577 cd	3.9 °
$I_{\text{FWTM}} 0.1 \cdot I_{\max}$	115 cd	15.1 °
Maximum range	1.0 nm	

2.1.4 White 7.4 V

The white signal light has a beam angle of 17.1° and a maximum range of 9 nm at night.

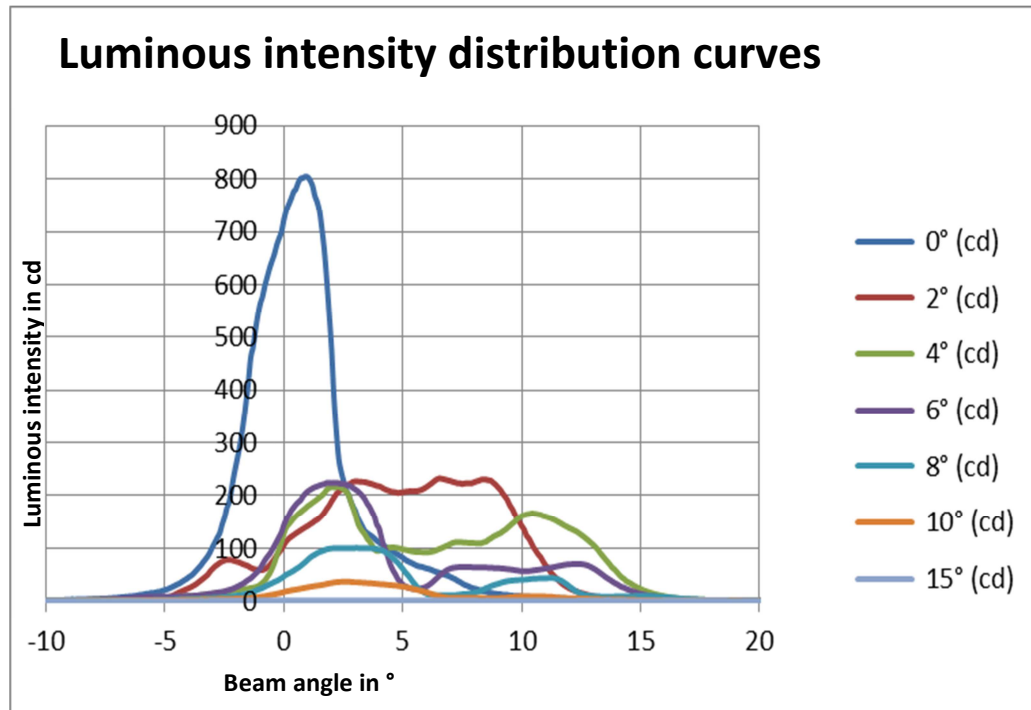


Figure 59: Luminous intensity distribution curves of white signal light at night

@ 0°	Luminous intensity	Beam angle
I_{\max}	723 cd	1.5 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	361 cd	3.8 °
$I_{\text{FWTM}} 0.1 \cdot I_{\max}$	72.3 cd	17.1 °
Maximum range	9.0 nm	

2.1.5 Red 7.4 V

The red signal light has a beam angle of 14.4° and a maximum range of 6 nm at night.

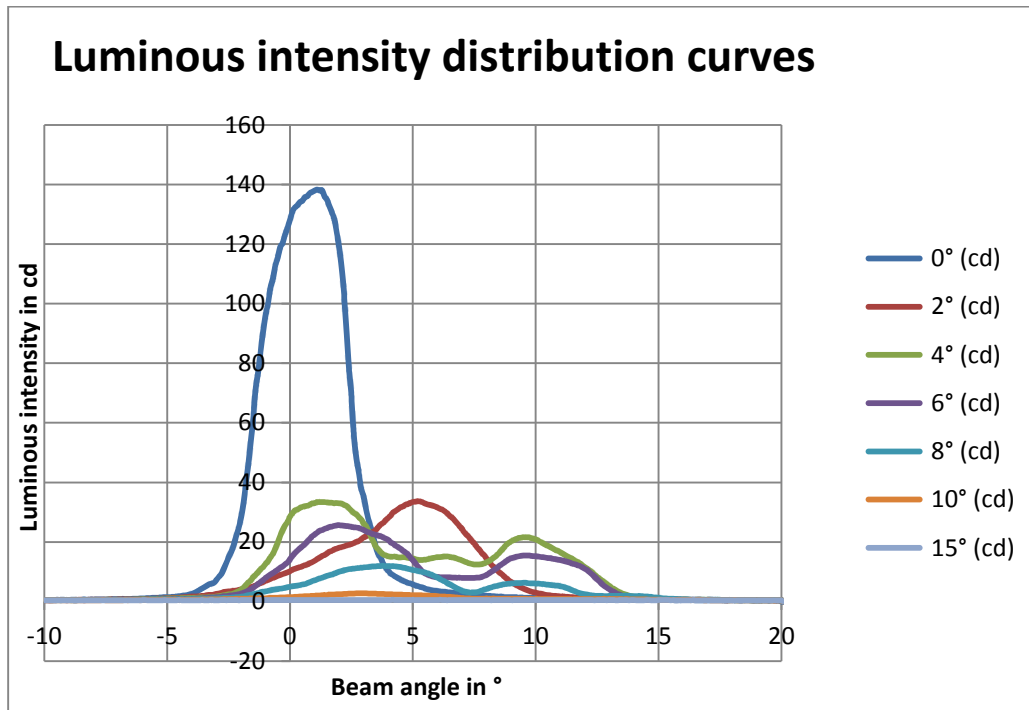


Figure 60: Luminous intensity distribution curves of red signal light at night

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	128 cd	1.8 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	64 cd	4 °
$I_{\text{FWTM}} 0.1 \cdot I_{\max}$	12.8 cd	14.4 °
Maximum range	6.0 nm	

2.1.6 Green 7.4 V

The green signal light has a beam angle of 14.8° and a maximum range of 6 nm at night.

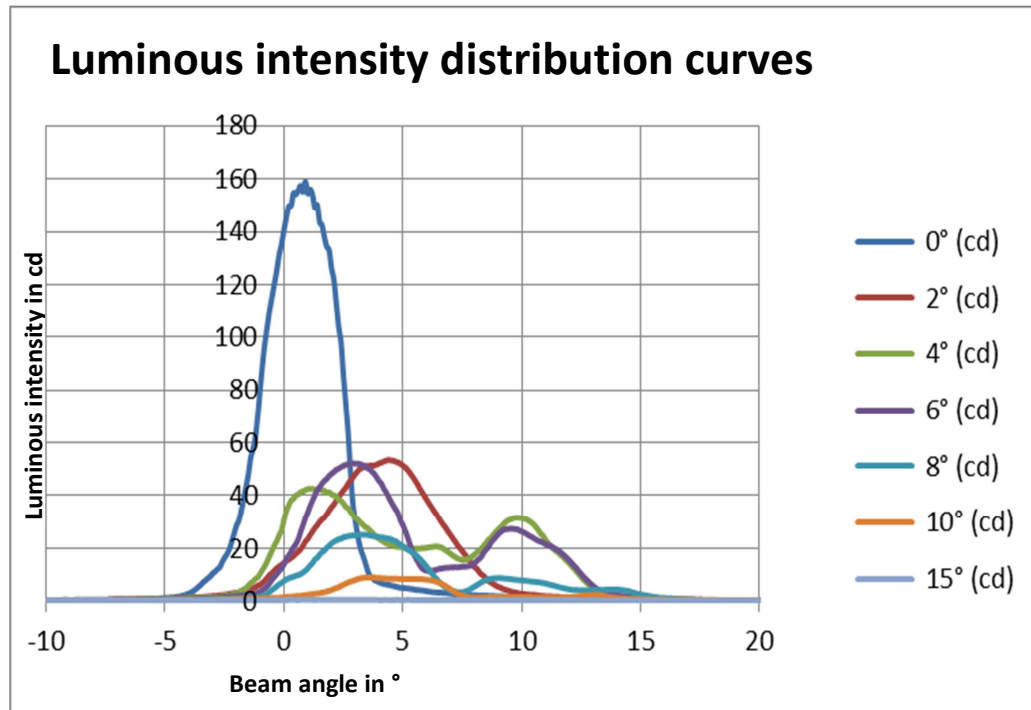


Figure 61: Luminous intensity distribution curves of green signal light at night

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	140 cd	1.6 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	70 cd	3.8 °
$I_{\text{FWTM}} 0.1 \cdot I_{\max}$	14.0 cd	14.8 °
Maximum range	6.0 nm	

2.2 Chromatic points (12 V day and 7.4 V night)

The chromatic points of the signal lights are largely within the range required by the IALA. Only the red light deviates significantly toward long wavelength red. However, this range is defined in DIN 6163 (Colours and colour limits for signal lights) as an additional red, for example. Consequently, it is still reasonable to assume that the colours were clearly visible.

2.2.1 White 12 V

The measured chromatic points of the white signal lights are largely within the white colour range.

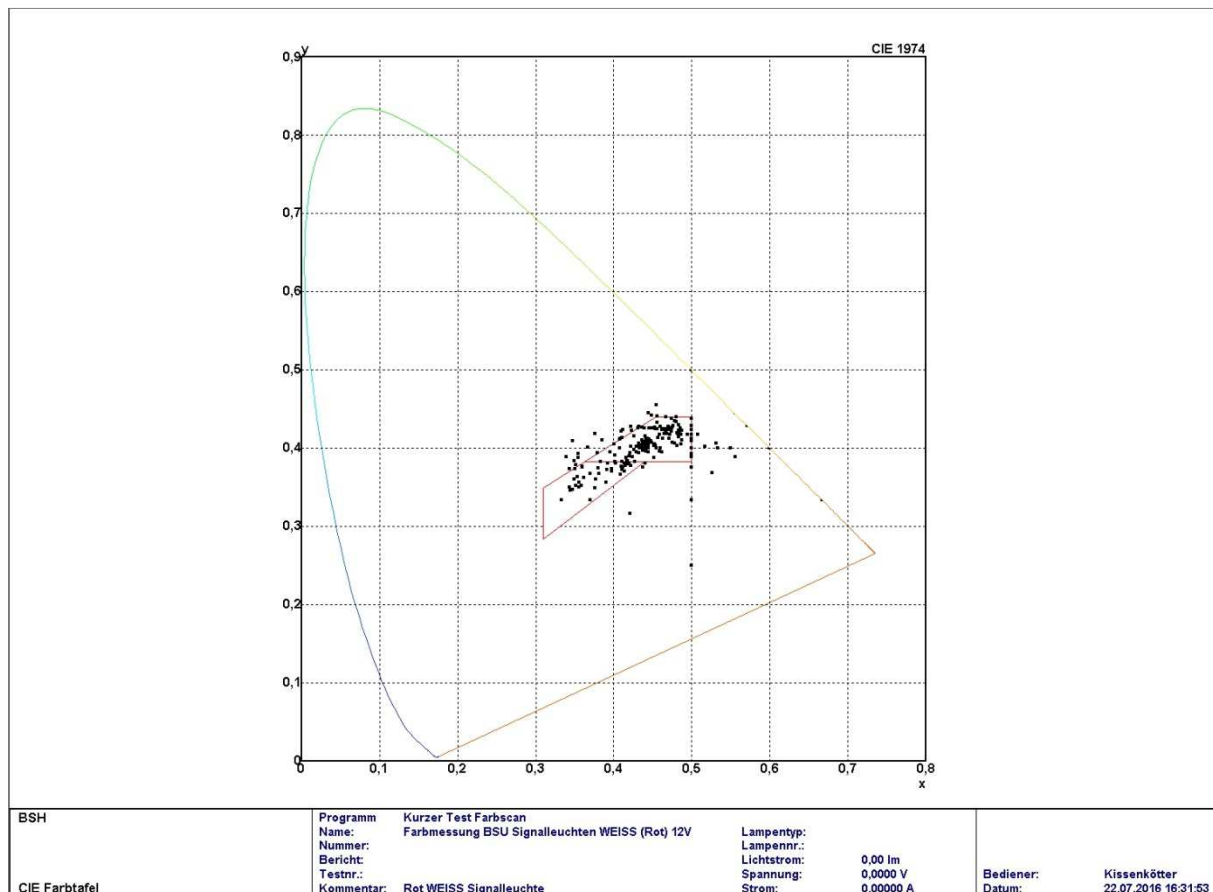


Figure 62: Colour measurement, 12 V WHITE, CIE chromaticity diagram

2.2.2 Red 12 V

The measured chromatic points of the red signal lights exhibit a clear tendency toward long wavelength from the red colour range.

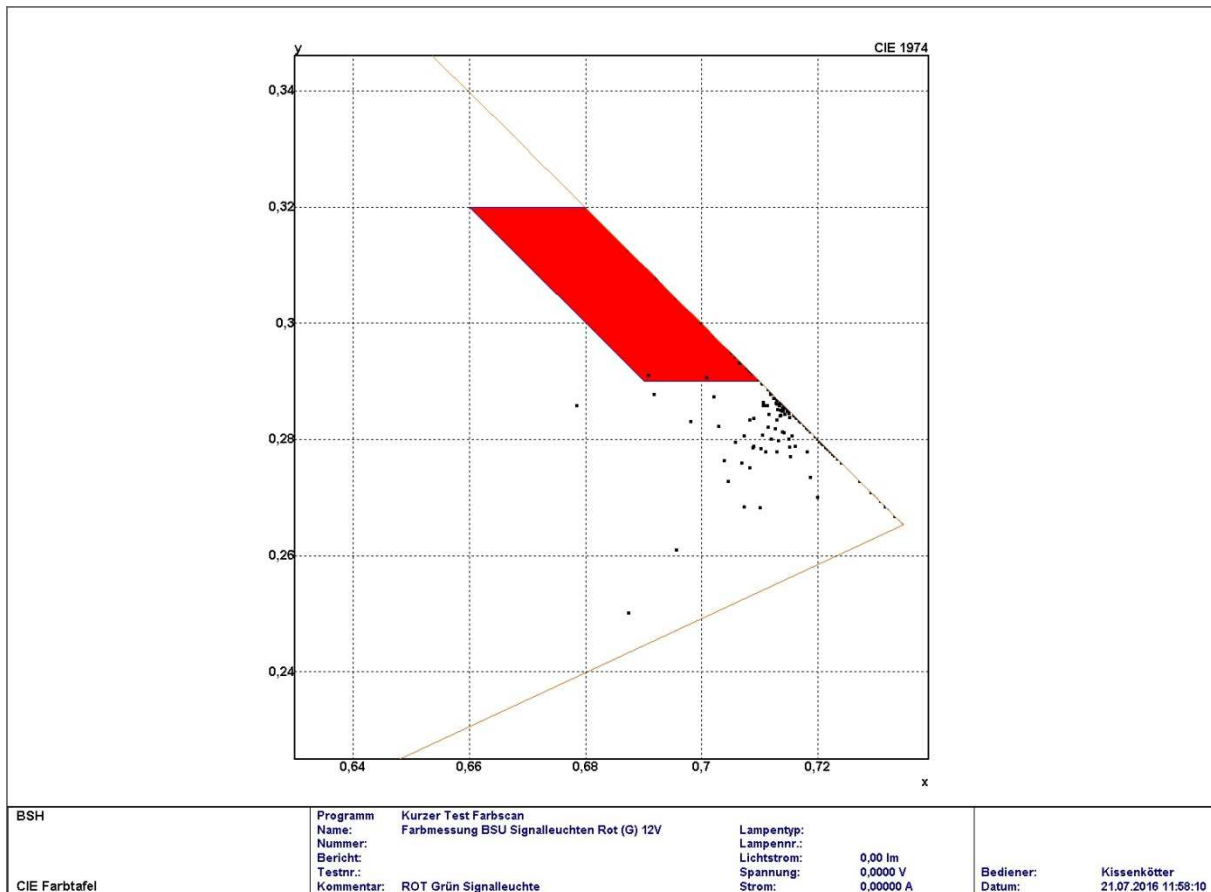


Figure 63: Colour measurement, 12 V RED, extract from CIE chromaticity diagram

2.2.3 Green 12 V

The measured chromatic points of the green signal lights are largely within the green colour range.

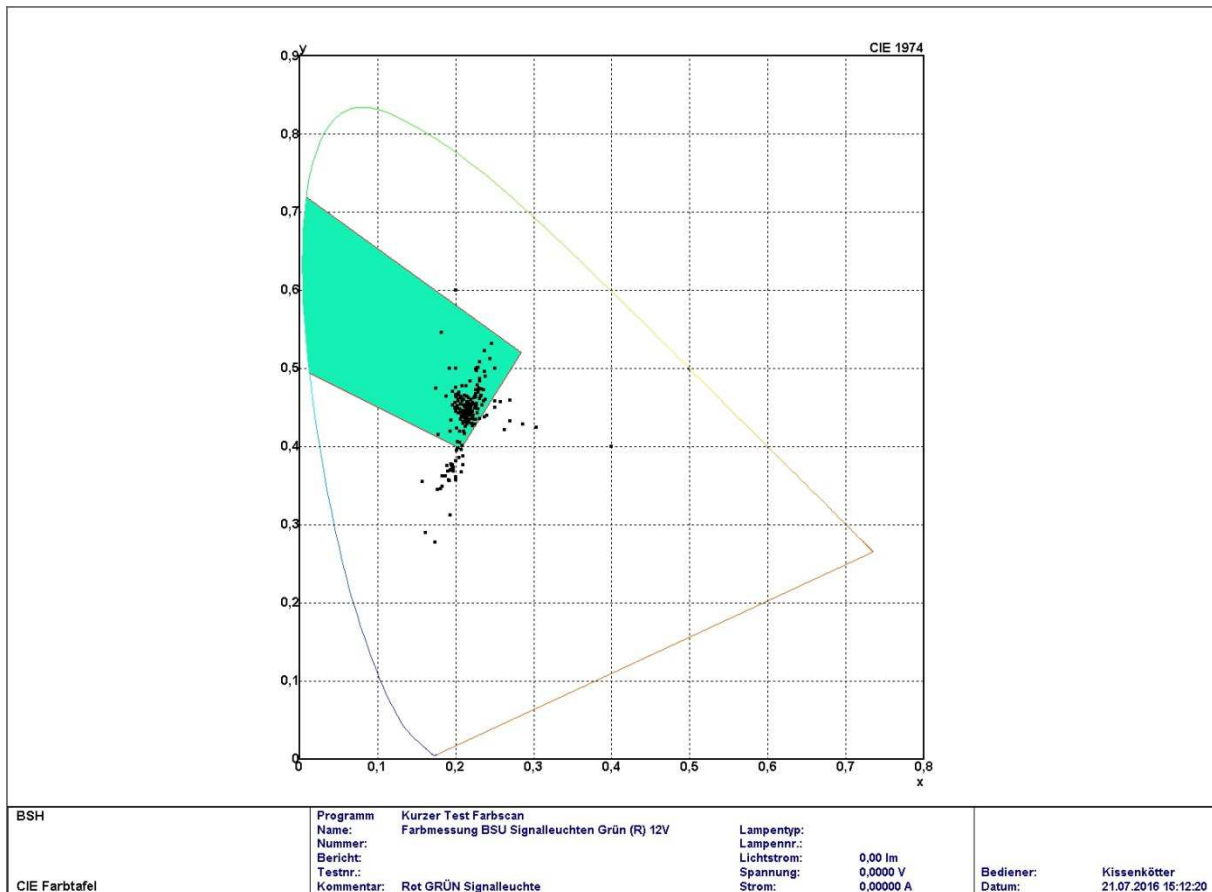


Figure 64: Colour measurement, 12 V GREEN, CIE chromaticity diagram

2.2.4 White 7.4 V

The measured chromatic points of the white signal lights are largely within the white colour range. A shift toward yellow is clearly visible.

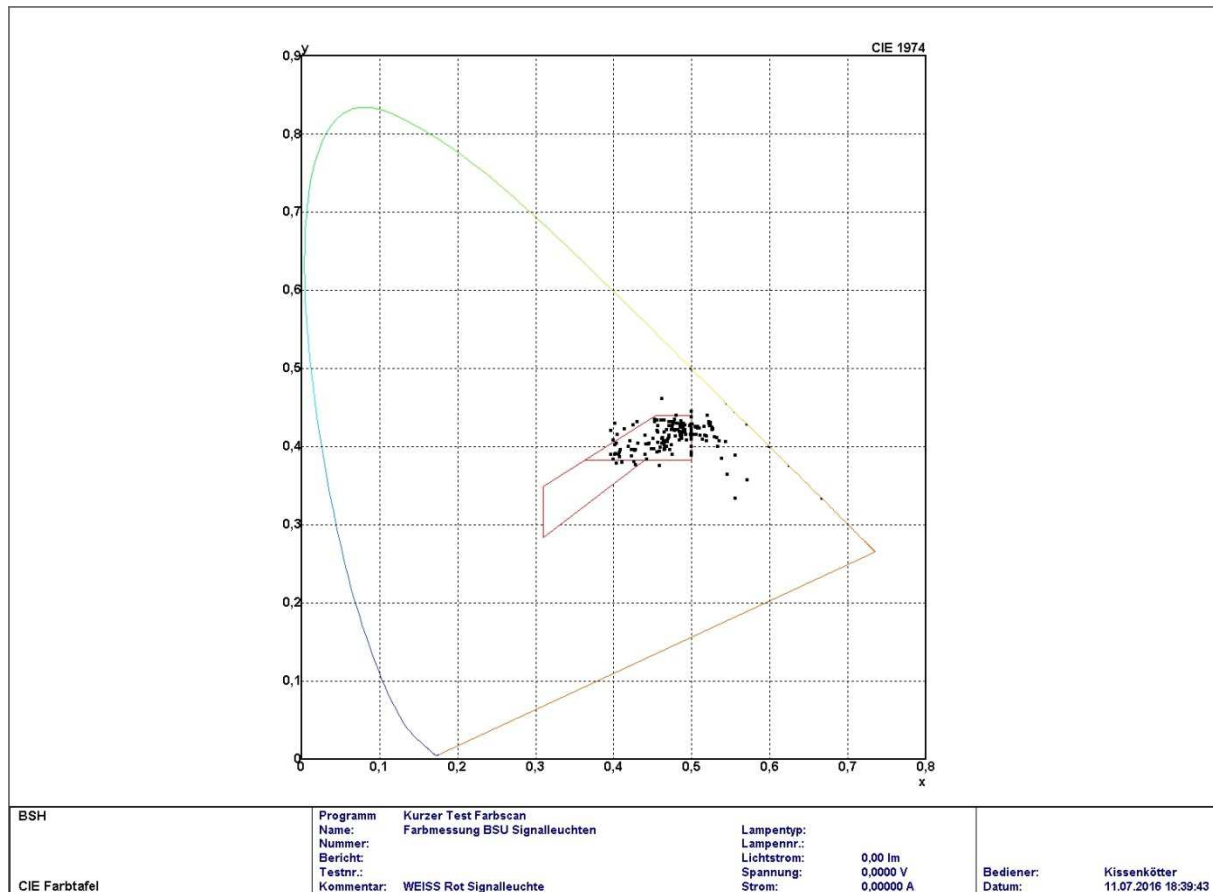


Figure 65: Colour measurement, 7.4 V WHITE, CIE chromaticity diagram

2.2.5 Red 7.4 V

The measured chromatic points of the red signal lights exhibit a clear tendency toward long wavelength from the red colour range.

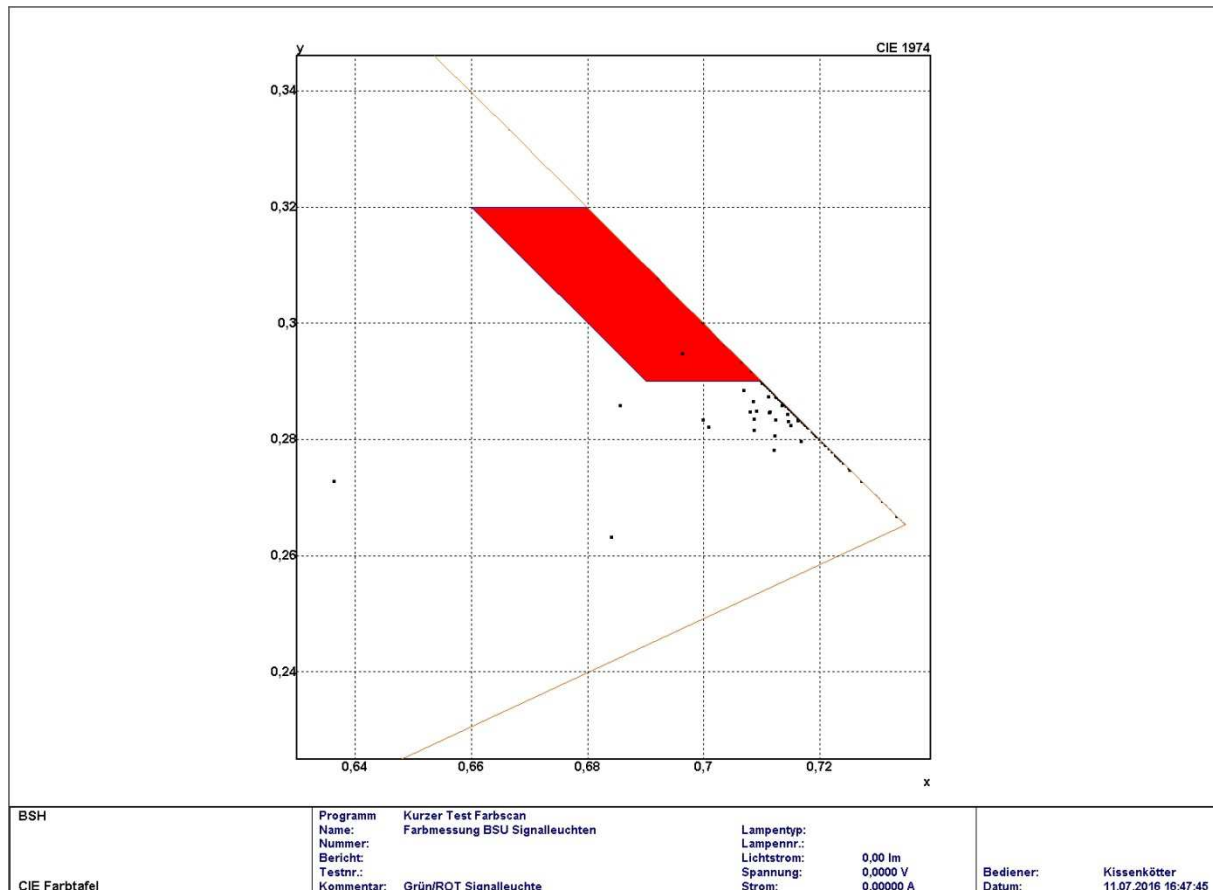


Figure 66: Colour measurement, 7.4 V RED, extract from CIE chromaticity diagram

2.2.6 Green 7.4 V

The measured chromatic points of the green signal lights are largely within the green colour range.

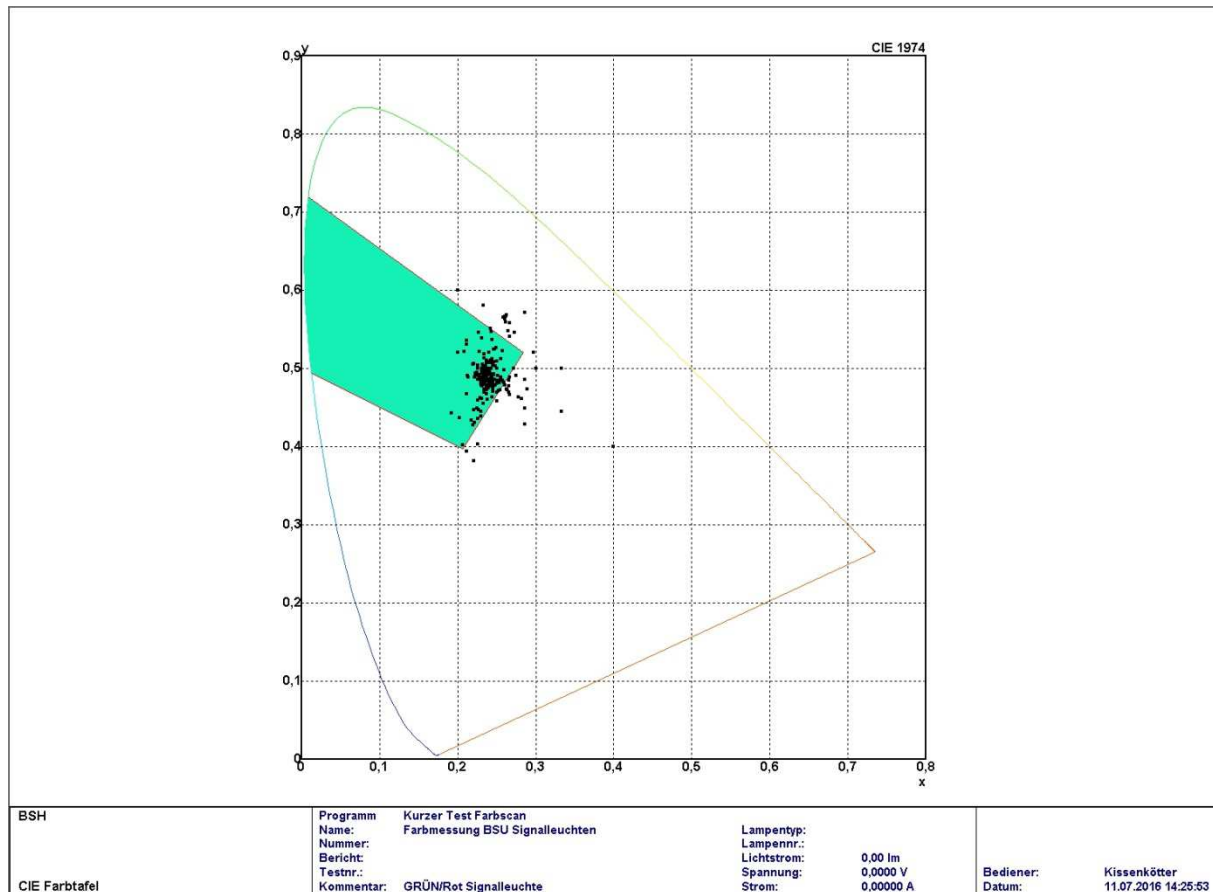


Figure 67: Colour measurement, 7.4 V GREEN, CIE chromaticity diagram

3 Investigation of the floodlight technology

A sodium vapour lamp used as background lighting (dolphin lighting) was also tested for range and dispersion angle in the BSH's photometric laboratory. The floodlight was equipped with an OSRAM VIALOX light source (Figure 73:).

The luminous intensity of this light is about 850 cd, meaning it has a range of 9 nm.

4 Assessment of the background and interference lighting

For the assessment of the measurement results, the background and interference lighting was first examined in more detail. The interference lighting was mainly due to the Klingele paper mill (Figure 71:), which represents the greatest source of interfering light in the vicinity. As can be seen clearly on Figure 70:, this source of interference is not in the direct field of vision when approaching the bridge and was therefore ignored in the following consideration.

Similarly, the dredger working in the area of the bridge was also not in the direct field of vision according to the knowledge available and therefore also ignored.

Several floodlights provided the lighting in the background of the Friesenbrücke Bridge. These lights were installed slightly higher than the signal boards at an angle of about 45° on the opposite side of the bridge (when approaching from the south) as notice board illumination (Figure 69:). After analysing the range and dispersion angle of the lighting in the background, it is reasonable to assume in a worst-case scenario (signal board directly in field of vision with lighting in background) that the lighting in the background reduces the range of the signal lights and thus diminishes visibility when approaching the bridge from the south.

The method shown in 'IALA Recommendation E-200-2 2 LUMINOUS RANGE FOR NIGHT TIME' was applied for an objective evaluation.

4.1 Reduced ranges, IALA E-200-2 at night 7.4 V

The source of interference and the signal lights are at the same distance from the observer. The range of the signal lights is some 6-9 nm and it is reasonable to assume that the interference lighting would have a luminous intensity of 850 cd in the worst case. Accordingly, the intensity of the interfering lights can be regarded as substantial. $V=10$ nm is applied for meteorological visibility on a clear day.

The reduced range of the signal lights at night can be determined from Figure 68:.

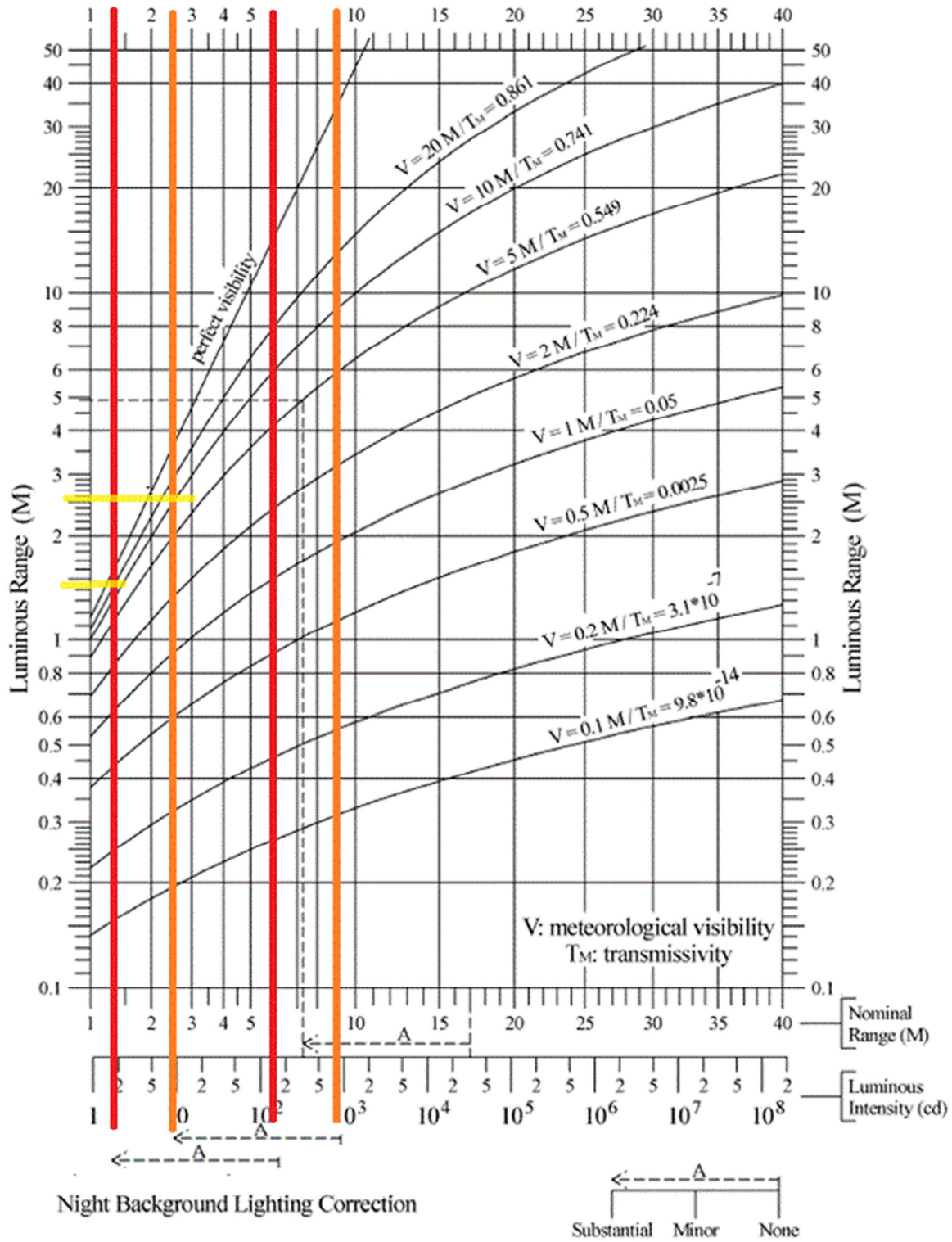


Figure 68: IALA E-200-2 (Figure 2: Luminous range diagram – night time)

4.2 Reduced range, white 7.4 V

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	723 cd	1.5 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	361 cd	3.8 °
$I_{\text{FTM}} 0.1 \cdot I_{\max}$	72.3 cd	17.1 °
Maximum range	9.0 nm	
Reduced range	2.7 nm	

4.3 Reduced range, red 7.4 V

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	128 cd	1.8 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	64 cd	4 °
$I_{\text{FTM}} 0.1 \cdot I_{\max}$	12.8 cd	14.4 °
Maximum range	6.0 nm	
Reduced range	1.45 nm	

4.4 Reduced range, green 7.4 V

@ $\alpha = 0^\circ$	Luminous intensity	Beam angle
I_{\max}	140 cd	1.6 °
$I_{\text{FWHM}} 0.5 \cdot I_{\max}$	70 cd	3.8 °
$I_{\text{FTM}} 0.1 \cdot I_{\max}$	14.0 cd	14.8 °
Maximum range	6.0 nm	
Reduced range	1.45 nm	

The reduced ranges of the signal boards all exceed 1.45 nm, meaning they were visible up until the curve in the river.

5 Conclusions

The signal boards used on the Friesenbrücke Bridge at Weener all had extremely moderate ranges, which could be rated sufficient when also taking into account glare and interference lighting.

The chromatic points of the signal lights are somewhat borderline. In particular, the red signal light deviates from the IALA colour range well into dark red. This too could be clearly recognised as red, however.

Due to the consistently low beam angle, close-range visibility could be limited (distance less than 0.3 nm from the bridge). However, the signal boards are visible from the exit of the last river bend about 0.8 nm before the bridge in spite of the paper mill and the dolphin lighting when approaching from the south.

According to the investigation of the lighting technology on the signal boards used on the Friesenbrücke Bridge at Weener, it can be concluded that they and thus the state of the railway bridge must have been sufficiently visible for a navigator from the water in a clear line of sight and presumed meteorological visibility of 10 nm not reduced by dust or smoke.

6 Pictures

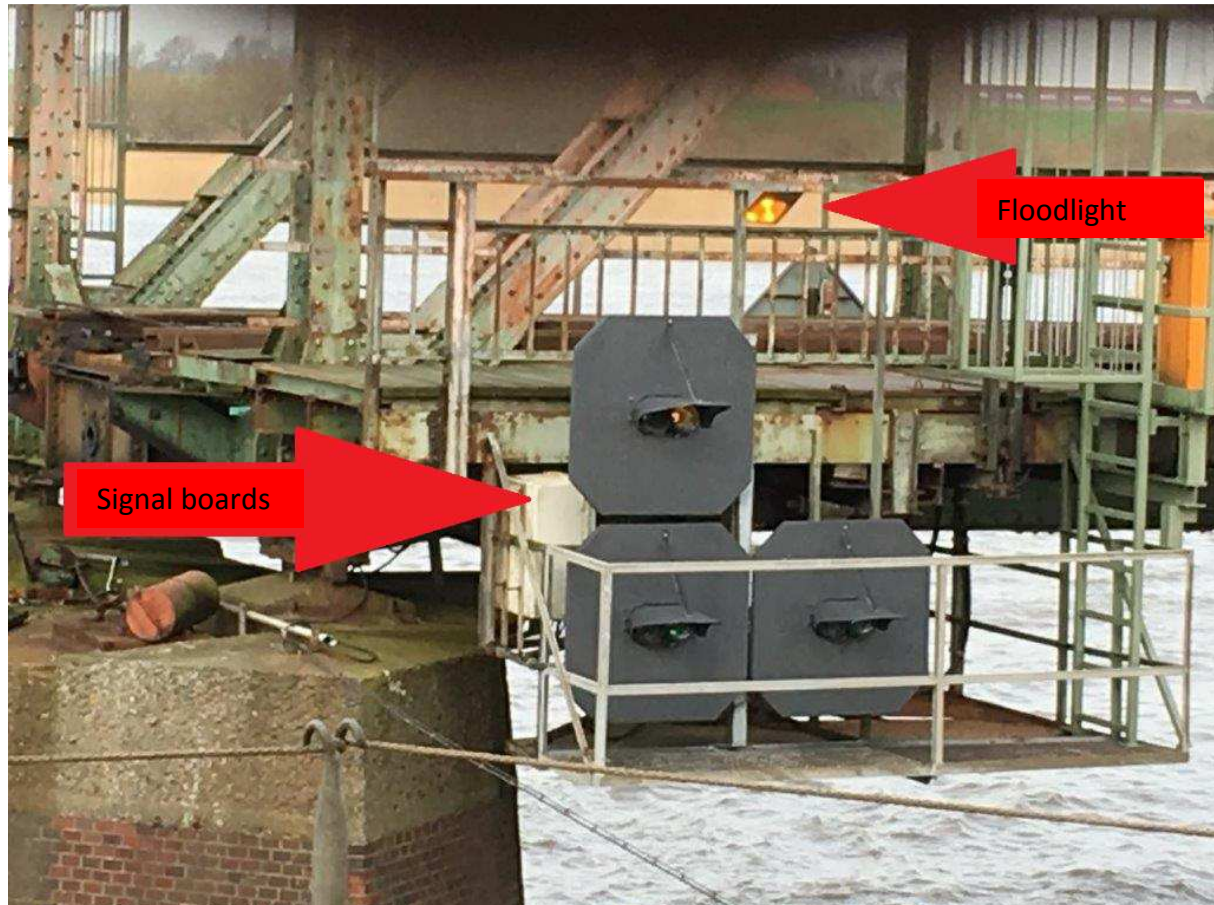


Figure 69: Signal boards with dual-element lighting units



Figure 70: Approach to the Friesenbrücke Bridge



Figure 71: Klingele paper mill

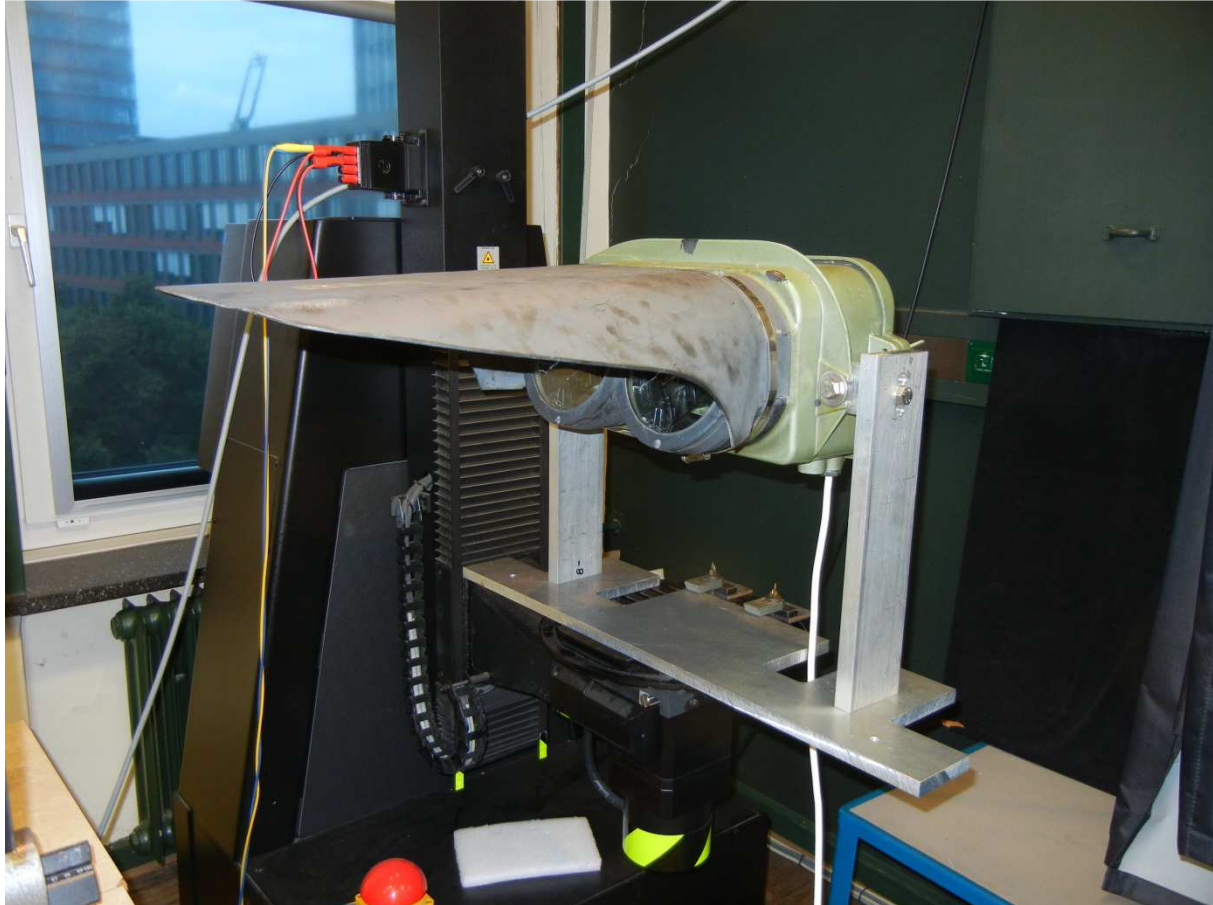


Figure 72: Dual signal light



Figure 73: Floodlight



Technical investigation of the radar system on the Emsmoon, Marine Casualty Investigation 470/15

Subject: **Radar system**

Type designation: **Furuno FR 21X5 (X-band),
VisionMaster (X-band)**

Report number: BSH 4533/000/3025/16

Contracting body: Federal Bureau of Maritime Casualty
Investigation
Bernhard-Nocht-Str. 78
20359 Hamburg
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Hamburg, 26 September 2016

By order

By order

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1 The ship

The Emsmoon (IMO No: **9213894**, MMSI: **304877000**, call sign: **V2BN3**) is equipped with two approved radar systems.

2 Installation of the radar systems

A Furuno FR 21X5 (X-band), scanner height 13.5 m, 21" monitor with 250 mm PPI is installed on the fore section and a VisionMaster (X-band), scanner height 25 m, 19" monitor with 250 mm PPI on the wheelhouse.

1. The installation site of the VisionMaster on the ship's wheelhouse delivers perfect all-round visibility, with the exception of a shadow sector at 270° caused by the mast at a distance of about 1.3 m.
2. The maintenance status of the device must be called into question and various faults are evident:
 - a. the VRM rotary knob on the control panel has been removed and is now missing;
 - b. the range index error does not seem to be properly compensated (curved shorelines);
 - c. a drawing of a radar shadow sector that is not consistent with the Emsmoon's superstructure is affixed to the right-hand side of the label on the device. It displays a shadow sector at some 130° to 160°. The current shadow sector at 270° ($\pm 10^\circ$) has not been hidden. This could be indicative of a retrofit with a used unit;
 - d. the images recorded by the voyage data recorder (VDR) show the contours of the surrounding shore only faintly. Since the settings on the VDR correspond with the default settings, which are noted on a label on the front, it is assumed that the magnetron has been used up. It is not possible to rule out whether the gain was set too low, causing a combination of both factors.
3. The installation of the radar antenna leads to a shadow sector of 48 m to the front, which reduces to 27 m for objects that protrude at least 3.5 m out of the water. This corresponds to the rules for unrestricted visibility from the bridge, which are used analogously for radar systems in Germany as a basis for assessment.
4. The deck produces strong false echoes ahead, especially when it is completely unladen.

5. The ship is fitted with a VDR according to SOLAS V.
6. The images recorded by the VDR originate from the VisionMaster. They appear to be incomplete. While parts of the display on the left-hand side of the display and in the upper part are missing, causing the absence of important information (heading, orientation, motion mode), a black border is visible on the right-hand side. Noise was recorded in the lower part of the display. Proper execution of the commissioning of the VDR and its annual inspection are questionable.
7. It is reasonable to assume that the radar system was serviced after the accident. According to the image documents found, the magnetron was exchanged and the sensor information available to the radar modified. Only the WT log failed to feed data on the voyage when the accident occurred. However, the heading and speed over ground (SOG), which should have been fed by the GPS, were absent during the voyage on 18 March 2016. This appears to be especially critical because the two speed values (SOG and speed through water (STW)) are written in green, indicating accurate data; only the course over ground (COG) is marked as lacking. Furthermore, it is not possible for the radar system to compute risk of collision by means of AIS without the GPS data.

3 Weather on 3 December 2015

The weather was not severe at this point, i.e. no fog or rain. Air and water temperature were about 10°C. The tidal information indicated an ebb tide. The tide peaked at Weener at 1754 CET.

4 Configuration of the VisionMaster FT on 3 December 2015

The VisionMaster FT appears to have been very poorly adjusted on the evening in question. Since a clear radar image was not configured, the target echoes are all diffused. This has already been addressed in section 2.d.

On the images from the day of the accident, no contours whatsoever are visible shore-side of the dyke, even though the scanner's installation height – some 5-6 m above the top of the dyke – would easily enable this.

Configuration of the radar system according to VDR:
Range 0.25 nm, head-up, relative motion enhance on.

According to the manufacturer's guide, the enhance on (enhanced video mode) function is active only from a range of 0.75 nm. Accordingly, the expected function, which was marked as active, is not active for the selected range of 0.25 nm.

5 Display of the bridge

The bridge has a construction height of some 12-14 m and is clearly visible, as are the five bridge piers. The system's resolution at this range scale (0.25 nm) is sufficient enough to easily distinguish between small objects, too. The VDR image clearly shows a tide gauge (1) and two measuring buoys (2), (3) in front of the bridge. The measuring buoys are equipped with corner reflectors, which would be able to show a non-precisely known RCS of more than 10 m^2 (therefore excellent reflectors). A wooden frame directly in front of the fourth bridge pier (from left) was not detected. This is explained by a distance of only 8 m from the pier, which exceeds the possibilities of the radial resolution. Moreover, the dyke and shoreline to the left are very weak but slightly stronger to the right. The strong echo of the bridge shows some internal structures, which can be explained by the complex lattice structure.

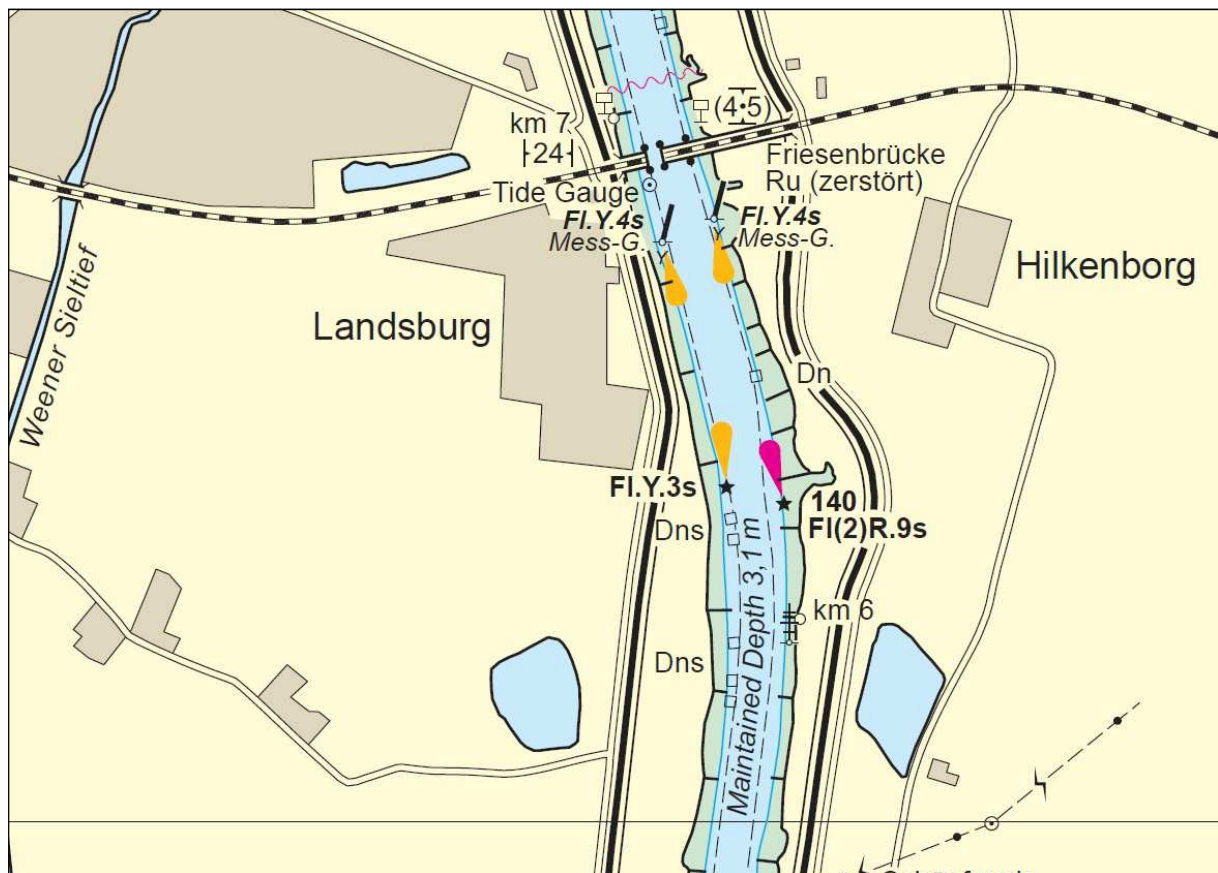


Figure 1: Extract from the 'Die Ems von Pogum bis Papenburg' (the Ems from Pogum to Papenburg), 1:25,000, Navigational Chart # 92 @ BSH



Figure 2: Satellite image from Google Maps taken before the accident

- 1 Tide gauge (level), distance from the bridge 42 m
- 2 Meter with light (Fl.Y.4s), distance from the bridge 148 m
- 3 Meter with light (Fl.Y.4s), distance from the bridge 160 m
- 4 Small wood frame in front of the base of the bridge, distance from the bridge 8 m

6 Analysis of the VDR radar recordings

1. On 3 December 2015, the VisionMaster detected and displayed the bridge for the first time according to the recording of the VDR at 182013 (VDR image 151203,172028,R1,9213894). The distance from the bow of the ship to the bridge at this point in time was 548 m \approx 0.296 nm (range was 0.25 nm) but off-centre (maximum view option) or 652 m \approx 0.352 nm from the radar antenna. This means that at a constant speed of 8.6 kts, the collision with the bridge would occur in 123 s if no action was initiated.

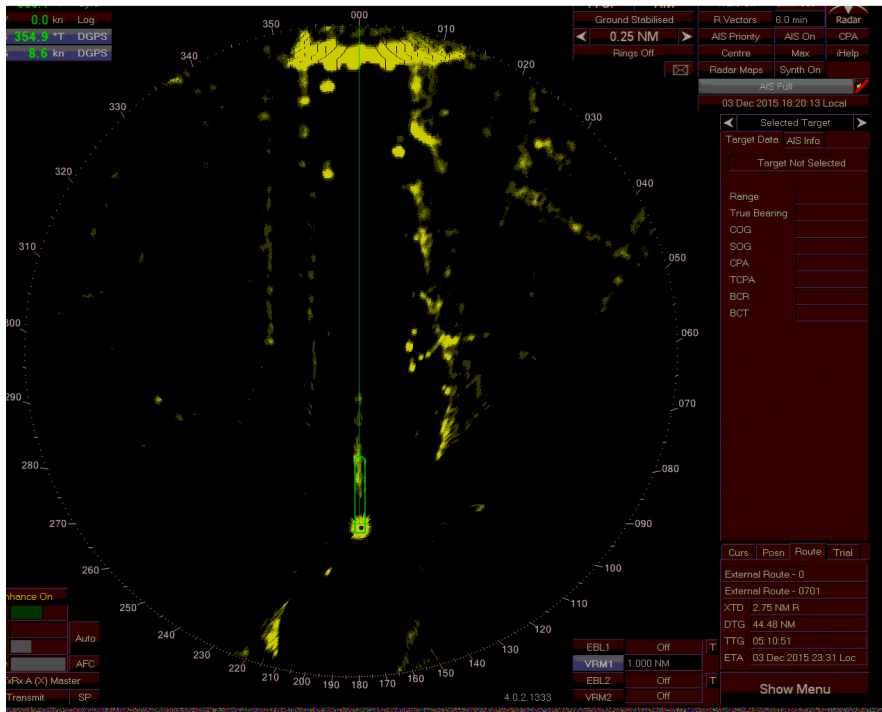


Figure 3: First recording of the radar image showing the bridge

Bridge passage area
before the accident

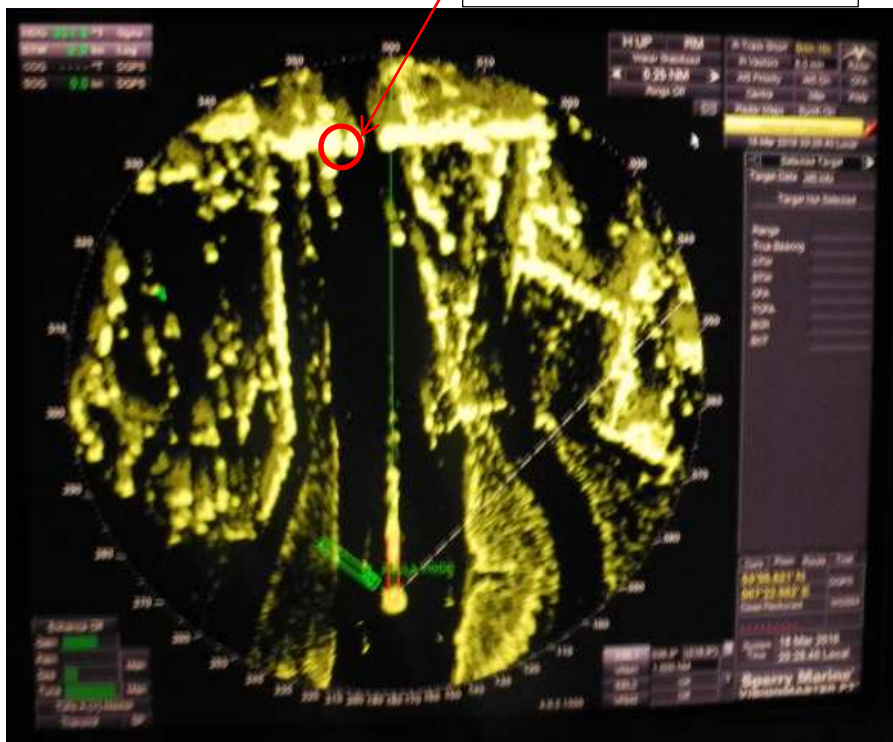


Figure 4: Comparative image (voyage on Emsmoon – 18 March 2016) showing the bridge after the accident

2. VDR image 151203,172058,R1,9213894 was recorded 30 seconds later. The distance from the ship's bow and radar antenna now stood at 431 m \approx 0.233 nm and 535 m \approx 0.289 nm respectively. The ship continued at about 8.4 kts, meaning the closed bridge was not noticed. The folding part of the bridge now shows a much weaker echo. The remainder of the bridge has changed only marginally and the objects (1-3) in the water are displayed just as clearly as 30 seconds earlier.

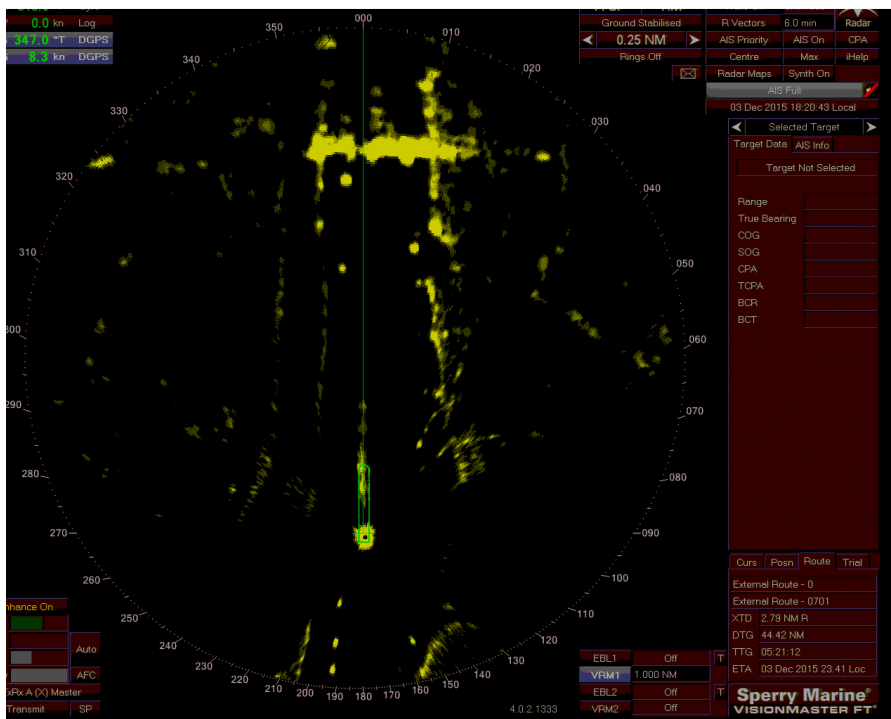


Figure 5: Second recording of the radar image showing the bridge

3. The following four VDR images, recorded up until immediately before the collision, show bridge echoes that are becoming increasingly diffused, and not only in the area of the bascule bridge. This could certainly lead to misinterpretations. This effect is not explained by the antenna's vertical radiation pattern. The angle to the foot of the bridge only reached 8° up until shortly before the collision, meaning it is within the guaranteed $\pm 10^\circ$ for vertical radiation patterns. Therefore, it can only be the structure of the lattice truss and elements that leads to reflections in all directions, as well as to extinction. That it is precisely the folding part which produces the poorest echoes in the VisionMaster, even though its structural design is no weaker than the rest of the bridge, is interesting. Extensive rust on the lattice elements leads to scatter and damping, which also worsens detection.

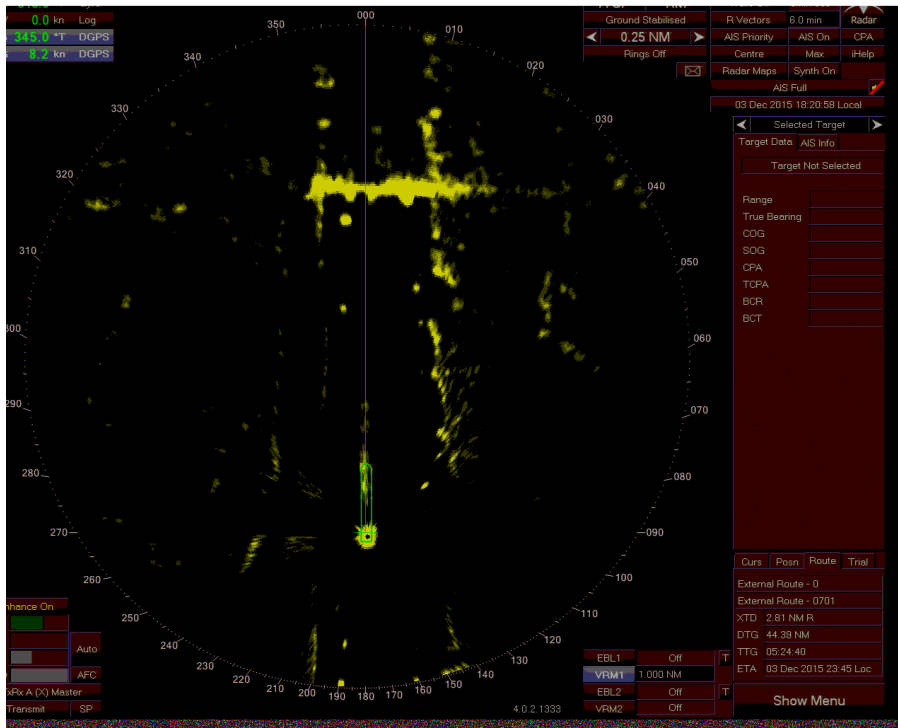


Figure 6: Figure 1 of 4

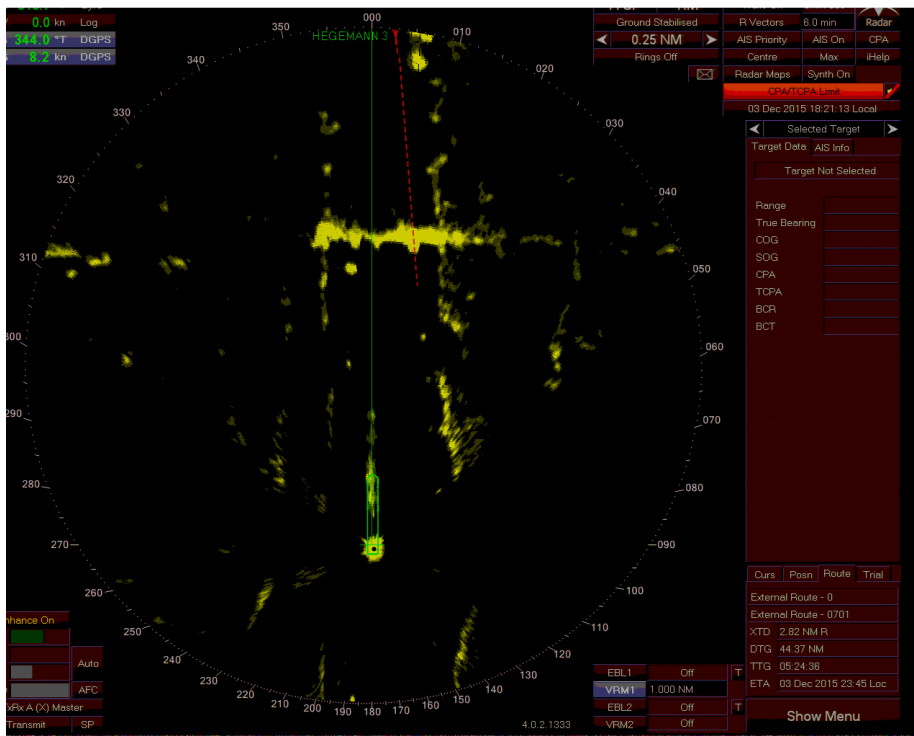


Figure 7: Figure 2 of 4

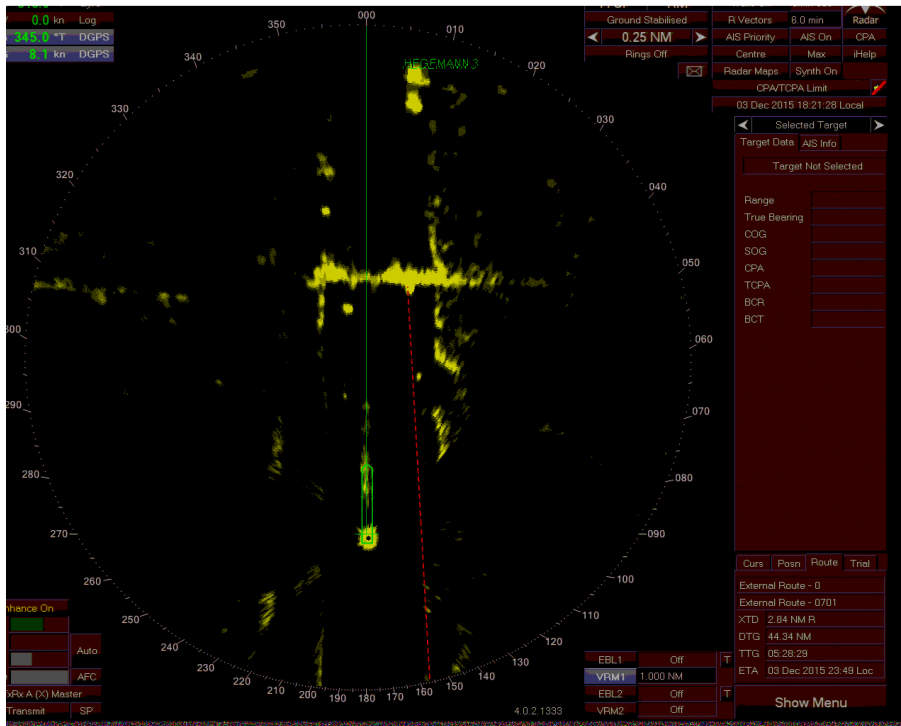


Figure 8: Figure 3 of 4

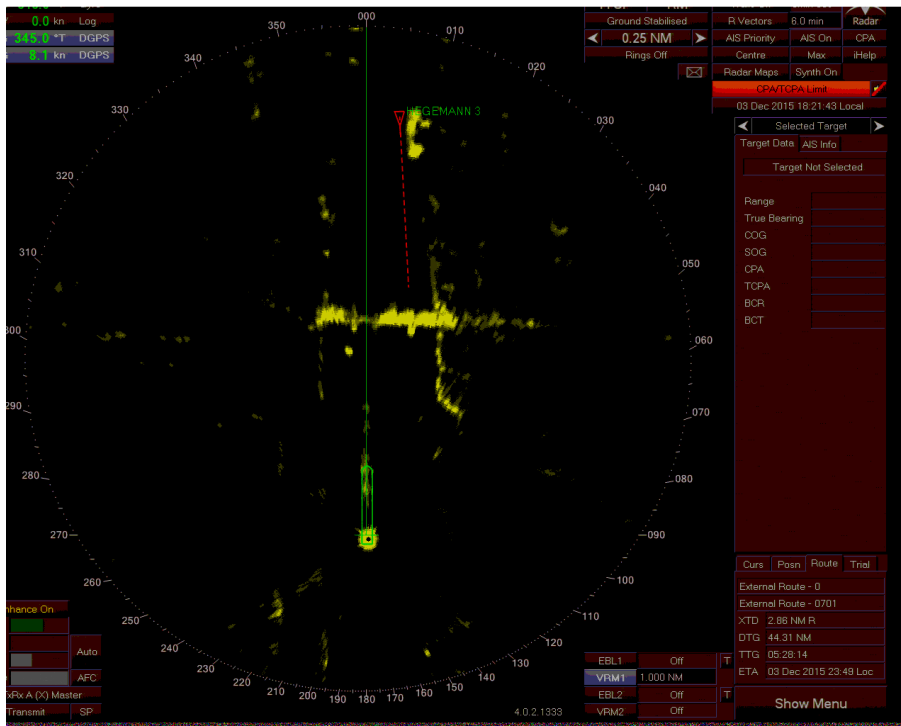


Figure 9: Figure 4 of 4

7 Findings

Although the Sperry VisionMaster FT radar system was poorly adjusted and exhibited technical deficiencies, it was clearly able to display the bridge and show that the passage was not open (see Figures 3 and 4). However, this would require that the Emsmoon's bridge team carefully observe the screen, as well as inwardly absorb and process all the consecutive images. It is questionable whether the range of 0.25 nm can be regarded as reasonable for a river voyage at more than 8 kts, as in addition to the insufficient potential warning time (123 s), it is also necessary to consider the extremely confined manoeuvring space, in particular. The distance from which it could be determined with the radar system that the bridge is not open is too short to take appropriate action to prevent an accident.

8 Technical measures to prevent a collision with the Friesenbrücke Bridge

➤ Transmission of information on AIS and display information on a navigation system

The IMO made it possible to transmit passage closures by means of AIS with the 'Marine traffic signal', which forms part of its Application-Specific Messages (ASM) (see Annex 1, SN.1/Circ.289, section 8).

While it is possible for these ASMs to be shown on a visual display unit in principle, a modification of the associated navigation system is required. This means that the manufacturer of the navigation device would need to develop and implement a corresponding upgrade in the system.

To display this on a portable pilot unit (PPU), which a pilot might be equipped with, appears to be more practicable, as they are acquired for and operated in the area.

The technical failure of the structure or ship cannot be precluded for as long as it is also possible to proceed when the bridge is closed. Consequently, the establishment, preparation and maintenance of an emergency mooring would seem advisable.

➤ Distance signal

A visual signal at a defined distance from the bridge would be another method of transmitting information early. The requirement for emergency mooring also applies here.

9 Operational measures

Establishment of a defined radio procedure

The firm definition of radio communications (preferably in the maritime mobile band to prevent the need for additional equipment and because all relevant bodies are integrated) would enable the definition of a safer procedure. However, it would be necessary to ensure that the approving body can issue shipping police orders so that the statements are binding in nature. The requirement for emergency mooring also applies here.

Annex 1 (SN.1/Circ.289)



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SN.1/Circ.289
2 June 2010

GUIDANCE ON THE USE OF AIS APPLICATION-SPECIFIC MESSAGES

- 1 The Maritime Safety Committee, at its seventy-eighth session (12 to 21 May 2004), approved SN/Circ.236 on Guidance on the application of AIS binary messages as prepared by the Sub-Committee on Safety of Navigation at its forty-ninth session (30 June to 4 July 2003).
- 2 The Sub-Committee on Safety of Navigation, at its forty-ninth session (30 June to 4 July 2003), selected seven (7) binary messages as shown in annex 2 to SN/Circ.236 to be used as a trial set of messages for a period of four years with no change. It was noted that four additional system-related messages were identified in Recommendation ITU-R M.1371 for the operation of the system.
- 3 The Sub-Committee on Safety of Navigation, at its fifty-fifth session (27 to 31 July 2009), after evaluating the use of binary messages in the trial period defined in SN/Circ.236, agreed on Guidance on the use of AIS Application-Specific Messages, including messages which are recommended for international use.
- 4 The Maritime Safety Committee, at its eighty-seventh session (12 to 21 May 2010), concurred with the Sub-Committee's views and approved the Guidance on the use of AIS Application Specific Messages, as set out at annex.
- 5 Member Governments are invited to bring the annexed Guidance to the attention of all concerned.
- 6 This circular revokes SN/Circ.236 as from 1 January 2013.

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